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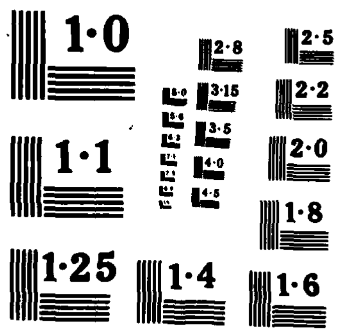
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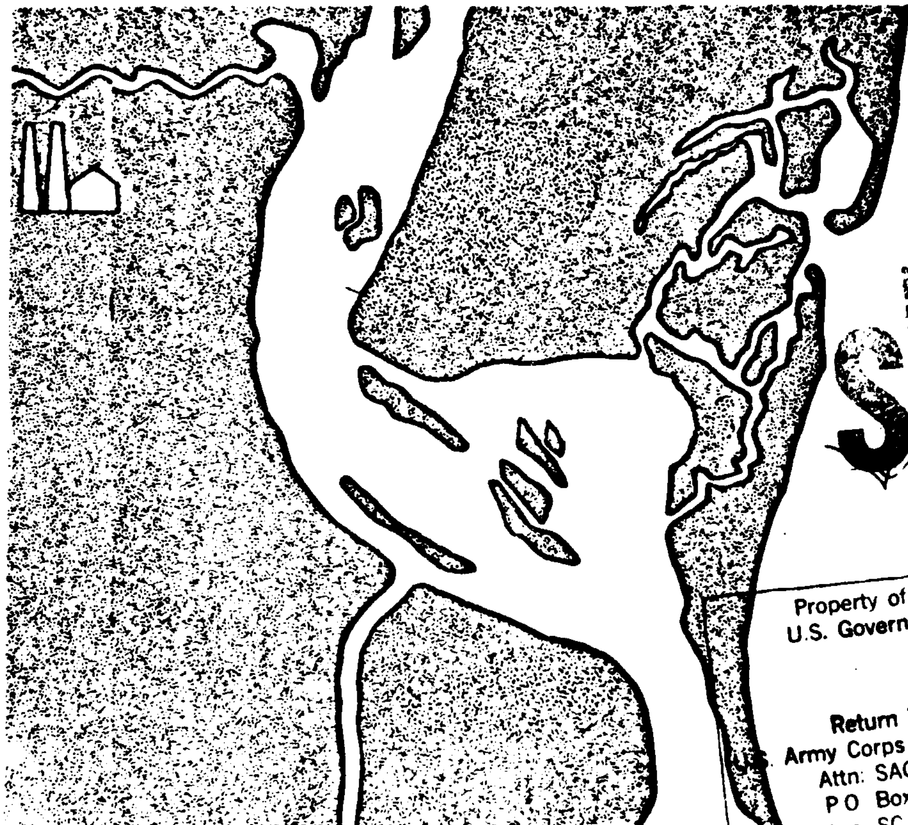
FINAL

ENVIRONMENTAL IMPACT STATEMENT
FOR
OIL REFINERY
GEORGETOWN, SOUTH CAROLINA

VOLUME 1



PERMIT APPLICATION
BY
CAROLINA REFINING AND DISTRIBUTING COMPANY

US Army Corps of Engineers
Charleston District

SEPTEMBER 1984

ERRATA SHEET

The following page numbers are not used: VII.C-14, VII.C-17, VII.C-18a, VII.C-20, VII.C-22, and VII.C-49.

Page VII.A-31, the sentence beginning on line 4 should be corrected to read: "Violations of the hydrocarbon standard may also cause violations of the ozone standard due to the role hydrocarbons play in ozone formation."

FINAL

ENVIRONMENTAL IMPACT STATEMENT

PERMIT APPLICATION
by
Carolina Refining and Distributing Company for Installation of Two Underwater Pipelines Across the Sampit River at Georgetown, Georgetown County, South Carolina

The lead agency is the U. S. Army Corps of Engineers, Charleston District, under authority of Section 10 of the River and Harbor Act of 1899. The cooperating agencies are the U. S. Fish and Wildlife Service (FWS), U. S. Environmental Protection Agency (EPA), and the U. S. Coast Guard. The EPA prepared all discussion of air and water quality and the FWS prepared all discussion of fish and wildlife resources.

Abstract: Carolina Refining and Distributing Company has applied for a permit to install two underwater pipelines across the Sampit River to transport crude oil and refinery products between the S. C. State Ports Authority pier and a proposed new oil refinery. This proposed refinery would enlarge the economic base of Georgetown County, one of the most economically depressed counties in South Carolina. The operation of the proposed refinery would however impact on air and water quality and aquatic resources in the area. These adverse impacts caused by air emissions and liquid effluents can be avoided or their severity reduced by the use of better treatment methods now available. Winyah Bay is surrounded by marshes and other natural areas, much of which are maintained in the public trust by State agencies and institutions and are considered to be of unusual value. Large oil spills are very unlikely but could cause extensive long-term damage to these areas. However, the Spill Prevention Control and Countermeasure Plan and the Operations Manual required by existing law provide measures to prevent and control oil spills.

If you would like further information on this statement, please contact:

Mr. John L. Carothers
U. S. Army Corps of Engineers
Charleston District
P. O. Box 919
Charleston, S. C. 29402
Telephone: 724-4258 or FTS 677-4258
Comments Must Be Received by _ ____________

SUMMARY

1. Description of the proposed project. Carolina Refining and Distributing Company has applied for a Department of the Army permit under the authority of Section 10 of the River and Harbor Act of 1899 to construct an underwater pipeline across the Sampit River at Georgetown, S.C. The purpose of this pipeline is to transport crude oil and refinery products between the S.C. State Ports Authority pier and a proposed new oil refinery to be located on the South side of the Sampit River.

2. Purpose and need for the proposed project. The proposed refinery would produce polygasoline, gas oil #2, fuel gas, aviation fuel, diesel fuel, and LPG (butane). These products can be competively marketed within a 100-mile radius of Georgetown and would contribute to the fulfillment of energy needs of this region. The public need for this project is represented by the demand for refined petroleum products.

3. Method of EIS preparation. The Charleston District asked the U.S. Fish and Wildlife Service (FWS), the U.S. Environmental Protection Agency (EPA, and the National Marine Fisheries Service (NMFS) to serve as cooperating agencies and to prepare input for those portions of the EIS within their areas of special expertise. The District prepared a tentative outline of the EIS. In connection with the scoping process, a list of suggested issues, and a description of alternatives were developed. The cooperating agencies ultimately determined the issues for analysis in their parts of the EIS. The FWS and EPA agreed to participate in the preparation of the EIS. The NMFS declined to participate in preparing the EIS because of manpower constraints, but the FWS agreed to include in its assignment those actions the NMFS had been requested to do. Subsequently, the U.S. Geological Survey was asked and agreed to prepare an evaluation of the effects of potential oil spills on ground water resources.

The participation of EPA, FWS, and the USGS has enabled the District to bring to bear at the beginning of the EIS process a much wider base of expertise. This resultant draft EIS is therefore more thorough and has incorporated a much broader perspective than would have been possible had it been prepared by a single agency. The divergent perspective and environmental evaluations of these participating agencies preclude full agreement on the magnitude of all impacts. This was foreseen but it was believed that the public interest and the decision-making process would be better served by an EIS prepared in this manner. The responsibility for the EIS and the decision on the permit application rests with the Corps of Engineers.

4. Favorable environmental impacts. The proposed refinery would enlarge the economic base of Georgetown County, one of the most economically depressed counties in South Carolina.

5. Adverse environmental impacts.

a. Air Quality. The analysis performed for this EIS using worst case meteorological conditions indicates that there could be violations of air quality standards for non-methane hydrocarbons and ozone and that all remaining 24-hour SO_2 increment in the Georgetown Class II area and the Class I area of Cape Romain might be consumed. However, the analysis required for the State air quality permit must show that all standards will be met and no remaining allowable increment will be exceeded before the permit can be granted. In general, the air quality impacts of the proposed facility are small. The following Table shows air quality standards and the estimated emissions from the refinery.

Pollutant	Measuring Interval	Air Quality Standard $\mu g/m^3$	Proposed Facility Maximum Impact $\mu g/m^3$
Suspended Particulate	24-hour	250	14.8
	Annual	60	1.0
Sulfur Dioxide	3-hour	1,300	137
	24-hour	365	82
	Annual	80	1.3
Carbon Monoxide	1-hour	40,000	27
	8-hour	10,000	24
Nitrogen Dioxide	Annual	100	5.0

Cumulative impacts on the environment are defined as the incremental effects of an action added to other past, present, and reasonably foreseeable future actions regardless of what agency or person undertakes such actions. In the case of the proposed CRDC refinery, cumulative air quality impacts would refer to the emission impacts from the proposed refinery added to the emissions impacts from other sources within the Georgetown area. These cumulative air quality impacts have been compared to the ambient air quality standards in order to determine if the facility would cause standard violations.

Currently there are 11 sources within the Georgetown area listed in DHEC's emissions inventory. The existing total emissions and the proposed CRDC estimated emissions are compared in the following table:

Pollutant	Existing Sources Total Emissions Metric Tons/Year	(Tons/Year)	CRDC Refinery Estimated Emissions Metric Tons/Year	(Tons/Year)
Suspended Particulates	1,529.5	(1,675)	90.7	(100)
Sulfur Dioxide	46,884.2	(51,646)	45.3	(50)
Carbon Monoxide	1,387.1	(1,528)	90.7	(100)
Nitrogen Dioxide	17,878.2	(19,694)	412.1	(454)
Hydrocarbons	477.5	(526)	1,888.2	(2,080)

The analysis concludes that unavoidable adverse air quality impacts would result from fugitive construction emissions, fugitive hydrocarbon emissions and sulfur dioxide emissions of the plant when combined with other existing sources.

Adverse impacts from construction activities include particulate emissions and pollutants associated with vehicle exhaust. A number of mitigative procedures are available to reduce these impacts; some of these methods are discussed in Section VII.A.1.

The adverse impacts resulting from hydrocarbon emissions during plant operations can be reduced through a strict preventive and corrective maintenance program. As part of these programs, monitoring of operations and air quality can be conducted to insure that all leaks are identifiable so that repairs can be made.

The main source of sulfur dioxide emissions from the proposed refinery is the exhaust gases vented from the Claus-Stratford Tail Gas Treating and Sulfur Recovery Unit. Although this recovery unit is efficient for the removal of sulfur from process gases, the exhaust gases can have high concentrations of SO_2. If these exhaust gases are vented through a stack that has relatively poor dispersive properties, ground level concentrations of pollutants can be high. Ground level concentrations can be reduced through various design considerations such as combining exhaust gases and venting through one stack.

b. Water Quality Construction activities for the refinery and pipeline could temporarily increase levels of turbidity, BOD/COD, and other pollutants in the Sampit River and upper Winyah Bay. Turbidity increases due to erosion and runoff from the site would not produce a significant peak impact on turbidity levels, but they may produce a chronic increase over the duration of construction. Dredging activities for pipeline installation in the river bed would produce a short-term increase in turbidity and ammonia levels.

Chemicals such as petroleum hydrocarbons or other pollutants associated with construction activities could reach the water through runoff or airborne deposition; however, they would produce a relatively small increase in ambient pollutant levels compared to industrial discharges presently operating within the area. There could be a slight cumulative impact on the water column and sediments from such construction.

Operation of the proposed refinery can result in introduction of pollutants to the waters of the Sampit River and Winyah Bay though wastewater discharges and potential spills.

Based on the estimated effluent values listed in Table VIII.B-7, refinery wastewaters would add about 90 kg of BOD and 324 kg of COD per day to the Sampit River. Compared to the present NPDES limits for BOD (over 6,000 kg/day) and COD (over 56,000 kg/day) from all industries discharging into the Sampit River, the additional impact from refinery discharge for these components would be small.

Discharge of ammonia from the proposed refinery could produce an increase in the ambient level of this potential pollutant, particularly near the outfall. The combined NPDES limit for ammonia presently discharged by other industries is no more than 94 kg/day. Expected discharge from the proposed refinery could add about 93 kg/day of ammonia, an increase of almost 100 percent. Depending upon the wastewater process ultimately chosen, however, the quantity of ammonia discharge may be considerably less than this estimated value.

The oxygen demand imposed by the ammonia in the refinery discharge was included in the overall oxygen demand modeled in the simulations discussed in Section VII.B.a.(1)(d), and very little dissolved oxygen level reduction was imposed.

The oil and grease component of the wastewater effluent also could increase ambient levels of oil and grease in the river and bay. Present industrial discharges of oil and grease are limited to about 539 kg/day. The refinery wastewaters are expected to add up to a maximum of 30.7 kg/day, which is a 5.7 percent increase. It is expected that most oil and grease components of the wastewater would sorb to suspended particles in the vicinity of the outfall and settle into the sediments. This process could create a large cumulative impact to river, and subsequently bay, sediments over time.

Sulfides and phenols in the refinery wastewater would produce a low cumulative addition to present discharge limitations. It is expected that the refinery effluent would add 5 kg/day of sulfides to a present discharge limitation of 366 kg/day, and 7.5 kg/day of phenols to a present limit of 940 kg/day.

Based upon the sum of present NPDES limitations on discharge for selected metals to the Sampit River; the refinery effluent would increase the discharged mass of copper, chromium and zinc by six percent, three percent and 2.5 percent, respectively. An overall cumulative increase in the levels of these metals in the sediments can be expected. Increases in ambient levels for most other metallic components in the wastewater would be negligible.

The Charleston District plans to build a dredged material disposal site near the refinery site. Runoff from such a disposal site could increase the level of suspended particles in the Sampit River near a proposed refinery outfall. This could result in an increase in the potential for sorption and deposition of refinery wastewater pollutants in the Sampit River near Pennyroyal Creek. The cumulative impact on the sediments in this area would be far greater than for farther downstream in the river or for locations in the bay, because tracer studies and mathematical modeling have demonstrated that refinery pollutants can accumulate in this vicinity and that flushing capability will be less than for downstream areas.

Although construction and operation of the refinery would degrade water quality in the Sampit River and Winyah Bay, project effects should not be sufficient to violate any water quality standards. The primary impact of construction would be a temporary increase in water turbidity from runoff and excavation in the Sampit River. The primary impact of the operation of the refinery would be the degradation of water quality due to the pollutants contained in the wastewater discharge. A significant increase of pollutants in sediments near the outfall is anticipated. Most of the oil and grease components, for example, would probably be retained in sediments near the outfall. Dispersion and dilution of this wastewater within the Sampit River and Winyah Bay should reduce most component concentrations in the water column downstream of the outfall as indicated by the results of modeling shown in Table VII.B-11.

Oil spills within the study area could impose a significant immediate impact. Cumulative impacts from spills would include deposition of oil in the sediments with possible chronic release of pollutants to the water column over a long period of time.

Impacts to water quality from plant and pipeline construction activities can be substantially reduced if all available mitigative measures are implemented. The actual extent of reduction of impact, however, is dependent upon variables that are difficult to quantify at the present stage of refinery design planning (Tables VII.B-1, VII.B-2, VII.B-3). Some levels of impact would be unavoidable, however, particularly with respect to temporarily increased turbidity and BOD loading from dredging activities for installation of the subaqueous pipelines.

As long as oil is transported through the Winyah Bay system, the potential for oil spills will exist. A large spill has a very low probability of occurrence and may never occur during the lifetime of this proposed refinery. Small spills have a much greater probability of occurrence and may be considered unavoidable over a long time. The impacts of spills are addressed in Section VII.B.2.b.

Runoff and small unavoidable handling losses are chronic pollutant sources which would continue as long as the refinery would be in operation. Although runoff sources could be substantially limited by good housekeeping procedures, small handling losses would always occur. The water quality impacts relevant to these losses are discussed in Section VII.B.2.a.(3).

The cumulative impacts from petroleum spills could be significant, depending upon the volume of spill and location. Small spills in the harbor or river would increase the ambient levels of petroleum hydrocarbons in the water column and sediments. This cumulative increase may be enough to create ecological problems that are more significant than the effects of individual spills. Large spills in the river or bay would produce initial levels of petroleum hydrocarbons in the water column that would far exceed ambient quantities introduced by industrial effluent or natural deposition. Large spills also would increase the levels of oils in sediments and shorelines; if these sources of hydrocarbons are remobilized during ensuing years, these areas would become additional chronic sources of petroleum hydrocarbons in the river or bay.

Runoff and small unavoidable handling losses are chronic pollutant sources which will continue as long as the refinery is in operation. Although runoff sources could be substantially limited by good housekeeping procedures, small handling losses will always occur.

c. Fish and Wildlife

The Winyah Bay estuary is unique in having over 60,000 acres of adjacent lands set aside in perpetuity for the purpose of research, education and conservation. The fish and wildlife habitats of the bay system are of national significance as a haven for endangered and threatened species as well as protected species, Species of Special Emphasis, wading birds and migratory waterfowl. The bay provides valuable nursery and feeding habitat for commercially and recreationally important fish and shellfish species, the principal anadromous fishery in the State for shad and sturgeon and an important fishery for striped bass and herring. A large portion of Winyah Bay is bordered by productive marsh wetlands, with 80% of the shoreline environments of the bay falling into the most sensitive categories with respect to oil spills.

There is little information available on which to base an accurate characterization of the Sampit River aquatic system. It appears as if the lower river is characterized by polluted disturbances from industry and periodic dredging; the mid-river segments may perform a brackish nursery role, and the upper freshwater segments support most of the recreational use.

The effluent from the proposed refinery would contain oil and grease and other pollutants designated by the Environmental Protection Agency as toxic, carcinogenic and/or bioaccumulative. This effluent would degrade water quality in an area already stressed by existing pollution sources and adversely affect aquatic resources to an undetermined extent. The adverse effects on aquatic resources would be greatest near the outfall in the lower Sampit River, but some effects could extend into Winyah Bay.

The occurrence of any of the seventeen hypothetical oil spills except cases 3 and 4 could have significant adverse impacts on the aquatic resources of Winyah Bay. A total spill of 140,000 barrels would severely damage the aquatic resources of the entire Winyah Bay estuary. Because of the large volume and the inclosed nature of Winyah Bay, the effects of such a spill would persist for many years. The occurrence of small spills would be of concern because of the cumulative incorporation of toxic hydrocarbons into sediments. The offshore spill scenarios involve the fouling of the North Inlet estuary and/or the coastline south of Winyah Bay, resulting in significant adverse effects on fish and wildlife resources.

d. Ground water Oil spills could result in the infiltration of oil into aquifers, with shallow aquifers being most susceptible.

6. Alternatives. The following alternatives were addressed:

a. Refinery sites:

1. Harmony Plantation, Georgetown, S.C.
2. Myrtle Grove, Georgetown, S.C.
3. Charleston, S.C.
4. Other unspecified sites in South Carolina

b. Pipeline routes:

1. Under the Sampit River to either of the Georgetown sites
2. Suspension of pipelines from a highway bridge across the Sampit River
3. Around the Sampit River to either of the Georgetown sites

c. Other methods of handling oil:

1. Mooring and pumping facilities on the south shore of the Sampit River
2. Single point mooring system several miles offshore

e. Permit Issuance

f. Permit issuance with conditions

g. Permit denial (No Action)

7. Issues to be resolved. The only options available to the Corps of Engineers in processing this permit application to a final resolution are:

a. Issue a permit according to the application. This would enable the applicant to construct the underwater pipelines across the Sampit River to serve the proposed new refinery. This option would eventually result in the impacts listed in 4 and 5 above. since the refinery would probably have to comply with the New Source Performance Standards developed by EPA for oil refineries which are much more stringent than the design evaluated in this EIS, the adverse impacts from refinery operation would be much less severe. The potential for oil spills and the impacts therefrom would continue to exist.

b. Issue a permit with conditions. Various conditions could be attached to the permit that would ameliorate potential adverse impacts. Some conditions could increase the cost of the facility and its operation enough to reduce economic benefits.

c. Deny the permit application. Denial of the permit application would probably result in the abandonment of the project by the applicant. The adverse impacts attributed to the proposed refinery would be avoided and the economic benefits to Georgetown would not be achieved.

8. Areas of controversy: Areas of controversy include:

a. Compatibility of an oil refinery with maintenance of environmental quality at Winyah Bay and environs.

b. The manner and extent that the effluent from an oil refinery would affect the natural resources values of Winyah Bay and its environs.

c. The likelihood and magnitude of oil spills

d. The immediate and long-term effects of oil spills on Winyah Bay and environs

e. The effectiveness of oil spill prevention and control measures in the particular situation at Winyah Bay

f. The secondary effects of a new oil refinery on Georgetown

g. The need for another oil refinery.

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Revised 4-12-84

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IV. PURPOSE AND NEED

The purpose of this proposed work is to provide a pipeline for the off-loading of crude oil from the S. C. State Ports Authority pier to the proposed Carolina Refining and Distributing Company site. The purpose of the refinery is to produce the folllowing:

a.	polygasoline	580 bbl/day
b.	gas oil #2	730 bbl/day
c.	fuel gas	2,061 bbl/day
d.	aviation fuel (JP4)	8,851 bbl/day
e.	Diesel fuel	14,157 bbl/day
f.	LPG (Butane)	824 bbl/day

The applicant says these products can be competively marketed within a 100-mile radius of Georgetown and would contribute to the fulfillment of energy needs of the region. The public need for this product lies primarily in the ready supply of refined products in the region. The project will have a positive impact on the tax base of Georgetown County which has, in recent years, lost vast acreages to tax-exempt land ownership and land uses. Also, approximately 90% of the jobs created by the refinery will be filled by locally hired people.

V. ALTERNATIVES

The applicant has investigated the suitability of various areas as a market for refinery products that could be met by a small refinery. A major consideration in this search was the necessity to find a market sufficiently distant from the oil pipeline corridors of larger oil companies that a small refinery would be economically competitive. Of various such sites located on the Atlantic coast, the only two in the Charleston District are in Charleston and in Georgetown. The Charleston site was found to be unsuitable as will be shown in the discussion of that particular site. The market area at Georgetown is perceived by the applicant to comprise an area within a radius of approximately 80 miles of Georgetown.

The following alternatives have been formulated which meet either or both the applicant's need for a refinery to supply the market in the vicinity of Georgetown or the public's needs for additional petroleum products.

A. Refinery Sites

1. Harmony Plantation, Georgetown, S.C. This is the site on which CRDC proposes to build its oil refinery. This site is on the south side of the Sampit River just upstream of the U.S. Highway 17 bridge (Site A on Figure V. 1). A detailed description of the Harmony Plantation site can be found in the Revised Environmental Assessment dated 30 April 1981.

2. Myrtle Grove, Georgetown, S.C. This site is located on the south side of the Sampit River between the proposed Harmony Plantation site and the Highway 17 bridge (Site B on Figure V. 1). Most of this site is upland and vegetated with mixed pine-hardwood timber; the remainder is in former wetlands that has been diked for the disposal of material dredged from Georgetown Harbor. Because of its proximity to the Harmony Plantation site, the environmental impacts of using this site should be practically identical to those attributed to the Harmony Plantation site and a separate detailed analysis is not warranted.

3. Charleston, S.C. This site is located on the Cooper River above the Amoco Chemical Plant (See Figure V. 2). CRDC applied to the South Carolina Department of Health and Environmental Control for an air quality permit to construct a refinery at this site. CRDC was advised that although there were no air quality problems in this area, essentially all of the allowable sulfur dioxide increment had been consumed and that off sets would have to be obtained before a permit could be issued. Off-sets were not available so the air quality application was withdrawn and consideration of this site was terminated.

4. Other unspecified sites in South Carolina. This alternative could satisfy the public need for petroleum products to the extent such needs would be satisfied by a refinery at the Harmony Plantation site. It would not meet the needs of the applicant because he was unable to identify satisfactory market conditions outside of Charleston and Georgetown. A summary-type discussion in general terms of the environmental impacts attributed to the use of the Harmony Plantation site should suffice as the environmental analysis of this alternative.

B. Pipeline Routes

Two 12-inch pipelines are needed to carry crude oil from the State Ports Authority (SPA) dock to the proposed oil refinery across the Sampit River. Brief descriptions of the pipeline routes are as follows with the various routes shown in Figure V.3. Route 3 is the route proposed by the applicant in the permit application.

1. Under the Sampit River to the Harmony Plantation site or to the Myrtle Grove site. A pipeline to either site would require the excavation of a trench six feet in depth across the river and a small amount of excavation in the marsh on the south side of the Sampit River.

2. Suspension of pipelines from the U. S. Highway 17 bridge. This alternative would not require any work in wetlands and would not be within the jurisdiction of the Corps of Engineers. Implementation of this alternative would require a permit from the S. C. Highway Department. The impacts of operating such a pipeline should be nearly identical to those for operating an underwater pipeline, but the impacts of construction would differ.

3. Around the Sampit River to the Harmony Plantation site or to the Myrtle Grove site. A pipeline could be routed from the SPA dock up the north side of the Sampit River approximately 12 miles to the head of the Sampit River then approximately 12 miles down the south side of the Sampit to either site. This pipeline route would cross several small streams and would impact several wetland areas. This alternative would be very costly and would have greater environmental impacts than other pipeline alternatives, and detailed analysis does not appear to be warranted.

C. Other Methods of Handling Oil

1. Mooring and pumping facilities could be constructed on the south shore of the Sampit River directly across from the SPA dock (See Figure V. 3). Mooring and pumping facilities on the same side of the river as the proposed refinery would eliminate the need to cross the river with pipelines.

2. A single point mooring system located several miles offshore. A work platform, underwater pipelines, buoys, etc. could be used to move crude oil from ships moored offshore to the proposed refinery. Design of the system would be critical because the system would have to be able to stand forces exerted from all points. Continuous and careful maintenance and supervision of the entire system would be necessary to detect and prevent spills. A single point mooring system would mean less ship traffic into the harbor. The single most important advantage of the single point mooring system is that it will allow the use of very large tankers in a way that is practical and economical. It should be noted, however, that the proposed refinery is small according to industry standards, therefore, the vessels delivering the crude oil can be smaller and deliveries less frequent. Such a system would cost more than one hundred million dollars, which appears excessive for a small refinery. It also does not appear to offer any significant advantage to this proposed refinery operation and a detailed analysis is not warranted.

D. Larger or Smaller Refineries

1. A larger refinery at Savannah, Georgia instead of the two small refineries at Savannah and Georgetown. This alternative could satisfy the public need for additional petroleum products but it would not take advantage of market conditions perceived by the applicant. The market area for the larger refinery at Savannah would necessarily have to intrude into areas adequately serviced by oil pipelines of larger oil companies. The applicant states that he cannot compete with existing pipelines. This alternative does not require a detailed analysis.

2. A smaller refinery at Georgetown. The shipping requirements would be less for a smaller refinery than for a larger facility and this could result in less potential for impacts associated with shipping. A smaller refinery would appear likely to have all the potential problems of a larger facility, but the magnitude of any actual events could be smaller.

E. Permit Issuance

F. Permit Issuance with Conditions

The Corps can condition a permit if necessary to meet a legal requirement, serve a public interest objective, or avoid or mitigate adverse impacts on fish and wildlife resources when there are no local, state, or Federal programs or policies to achieve the desired condition and an agreement, enforceable at law, between the applicant and the parties concerned with the resource is not practicable.

G. Permit Denial (No Action).

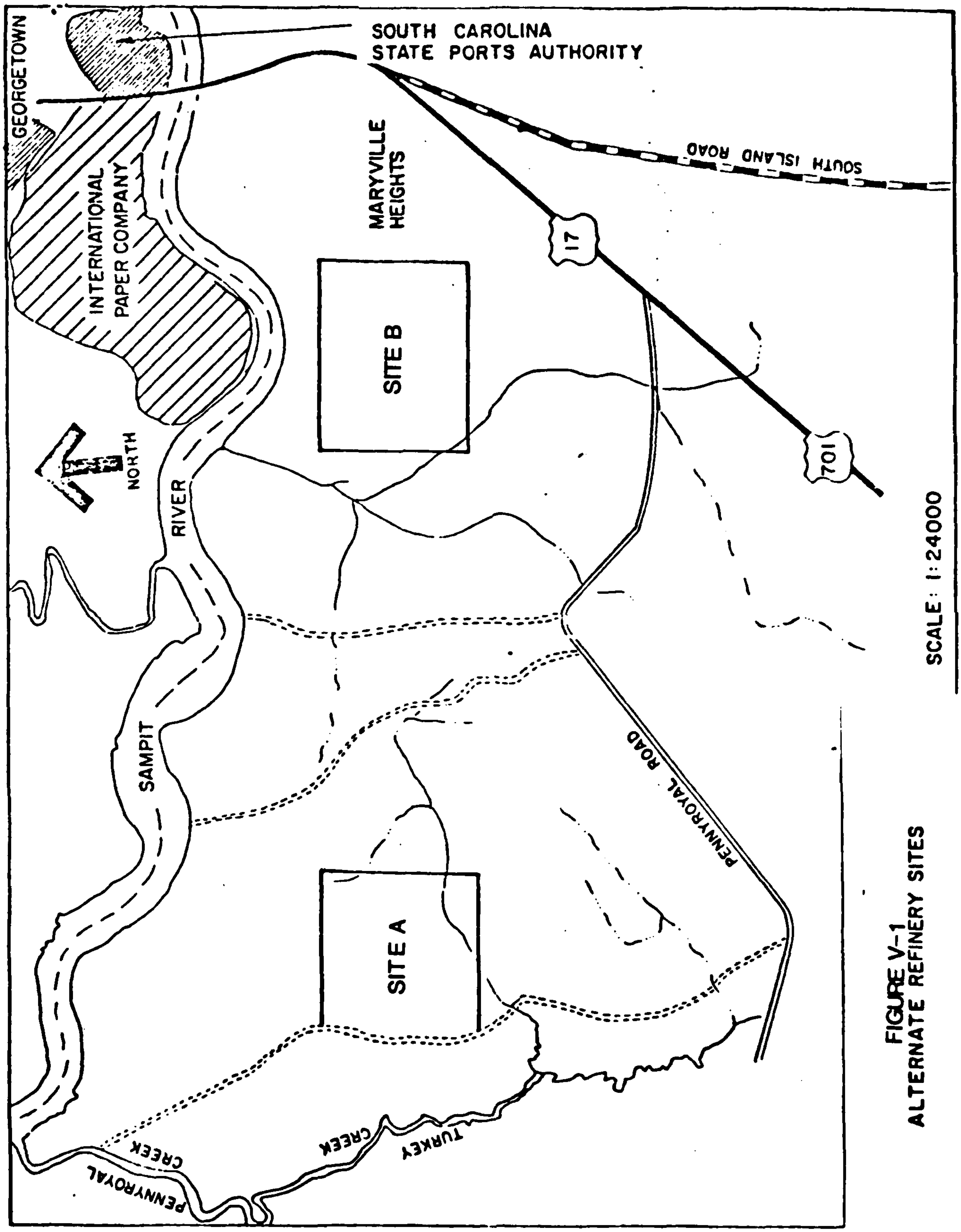
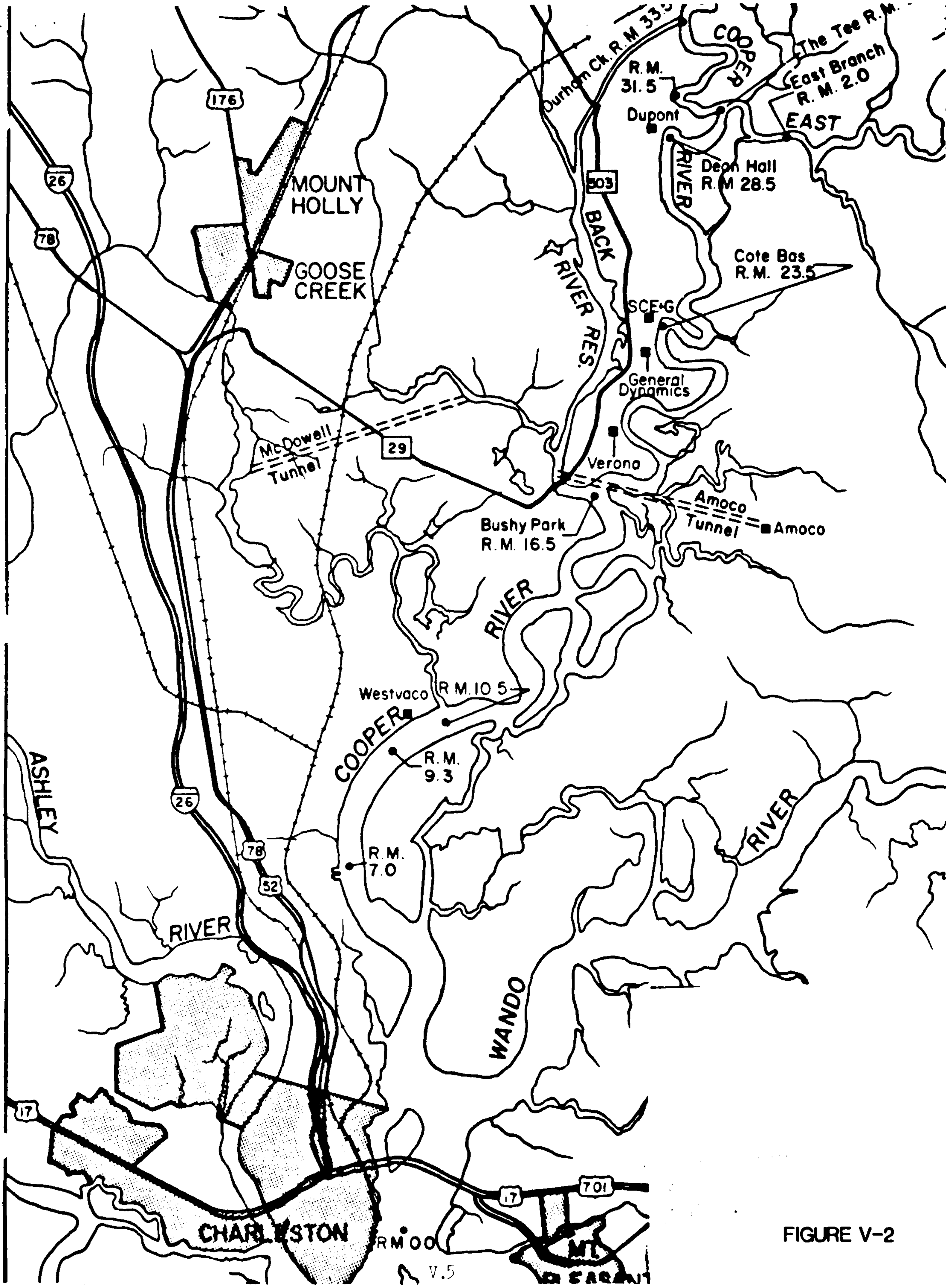
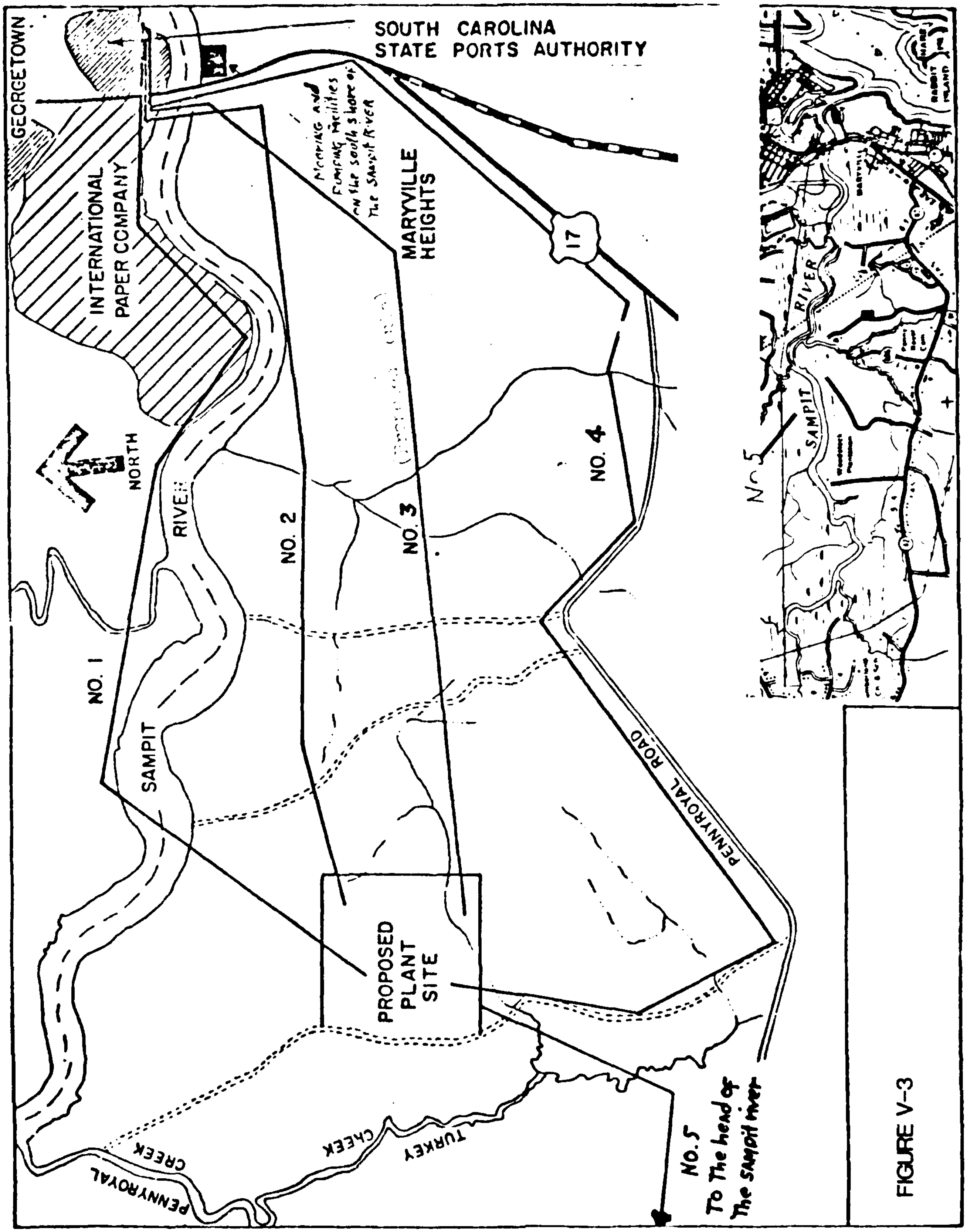


FIGURE V-1
ALTERNATE REFINERY SITES



MOUNT HOLLY
GOOSE CREEK
Durham Ck. R.M. 33.
COOPER
The Tee R.M.
East Branch R.M. 2.0
R.M. 31.5
Dupont
EAST
Dean Hall R.M. 28.5
RIVER
BACK
RIVER RES.
Cote Bas R.M. 23.5
SCE·G
General Dynamics
McDowell Tunnel
Verona
Amoco Tunnel
Amoco
Bushy Park R.M. 16.5
RIVER
Westvaco
R.M. 10.5
COOPER
R.M. 9.3
R.M. 7.0
ASHLEY
RIVER
WANDO
RIVER
CHARLESTON
RM 0.0
176
26
78
29
503
52
17
701

FIGURE V-2



SOUTH CAROLINA
STATE PORTS AUTHORITY
GEORGETOWN
INTERNATIONAL
PAPER COMPANY
Mooring and Pumping facilities on the south shore of The Sampit River
MARYVILLE
HEIGHTS
17
NORTH
SAMPIT
RIVER
NO. 1
NO. 2
NO. 3
NO. 4
PROPOSED
PLANT
SITE
PENNYROYAL ROAD
PENNYROYAL CREEK
TURKEY CREEK
NO. 5
To The head of
The Sampit river
SAMPIT
RIVER
NO 5

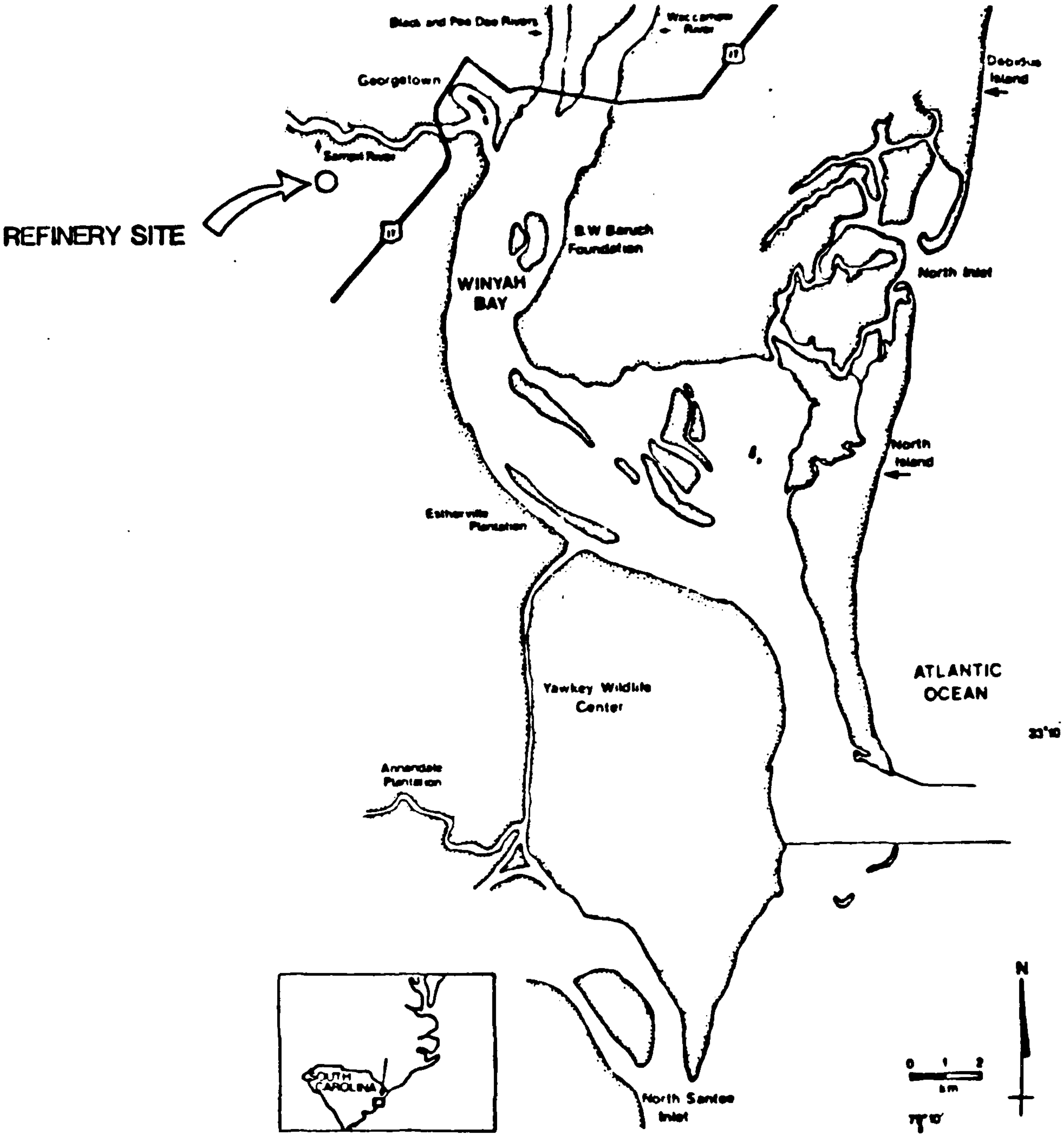
FIGURE V–3

..ES

	PIPELINE			LARGER OR SMALLER REFINERIES		
S SPENDED FROM HWY 17 BRIDGE	9. AROUND THE SAMPIT RIVER	10. PUMPING FACILITY ON SOUTH SHORE	11. SINGLE POINT MOORING SYSTEM	12. Enlarging The Proposed Refinery at Savannah, GA	13. Decreasing the Size of the Refinery at Harmony Plantation	14. PERMIT ISSUED WITH CONDITIONS
	No significant impact.		No significant impact.	A larger refinery is not economically viable. Minor degradation at Savannah but would probably meet all NAAQS.	The magnitude of all impacts, adverse and beneficial, would be proportionately less than that attributed to the proposed refinery (See Col. 3).	Depending on conditions, could further reduce effects now considered minor.
	Greater impact than other pipeline routes because of greater length.		Greater impact than other pipeline routes because of greater length.	Increasing the size of refinery would further reduce water quality at Savannah, but would probably not violate water quality standards.		Depending on conditions, could greatly reduce the adverse effects of waste discharge stated in Col. 3. Large spills unlikely, but potentially very damaging.
	No significant impact.		No significant impact.	No impact at Georgetown, but future base condition may change significantly due to other developments. Minor adverse impact at Savannah.		Depending on conditions, could further reduce effects of waste discharge now considered minor; large spills unlikely, but potentially very damaging.
	No significant impact.		No significant impact.	Minor adverse impact at Savannah.		Depending on conditions, could further reduce effects of waste discharge now considered minor; large spills unlikely, but potentially very damaging.
	No significant impact.		No significant impact.	Minor adverse impact at Savannah.		Depending on conditions, could further reduce effects of waste discharge now considered minor; large spills minor; large spills unlikely, but potentially very damaging.
	No significant impact.		No significant impact.	Major increase in economic base; an increase in highway traffic.		Depending on conditions, could increase costs to the extent that economic benefits could be reduced; an increase in highway traffic.
	No significant impact.		No significant impact.	Probably no impact at Savannah, but not evaluated.		No impact.
	No significant impact.		No significant impact.	Probably no impact at Savannah, but not evaluated.		Depending on conditions, could further reduce the potential of spills which could damage shallow aquifers.

TABLE
COMPARISONS

	1. BASE CONDITION	2. PERMIT DENIAL	REFINERY 3. HARMONY PLANTATION (Permit Applied For)	4. MYRTLE GROVE	5. CHARLESTON	6. OTHER UNSPECIFIED SITES	7. UNDER TH… SAMPIT …
AIR	Meets all national ambient air quality standards (NAAQS).	No impact; but future base condition may change significantly due to other developments.	Minor degradation; present design could violate some standards. Facility can not be permitted unless the refined analysis of final design by SCDHEC shows air quality is below the NAAQS.	Because this site is so near and similar to the Harmony Plantation site, the impact of a refinery here would be similar to Col. 3.	A refinery cannot be constructed in Charleston because there is no available SO_2 increment and the required air quality permit cannot be obtained.	Minor degradation at any other site.	No significant impact
WATER	Winyah Bay & Lower Sampit River are classed by the State as S.C. waters. The lowest of 4 classes. Most recent 3-year study by SCDHEC shows a trend of declining quality in Winyah Bay.	No impact; but future base condition may change significantly in response to other developments.	Normal operation would degrade quality. Water quality standards will be maintained by NPDES requirements. Spills can have a long-term adverse effect. Large spills very unlikely but potentially very damaging to a large area. Small spills much more likely, but much less damaging to a smaller area.		Normal operation would degrade quality. Water quality standards will be maintained by NPDES requirements. Spills can have a long-term adverse effect. Large spills very unlikely but potentially very damaging to a large area. Small spills much more likely, but much less damaging to a smaller area.	Normal operation would degrade quality. Water quality standards will be maintained by NPDES requirements. Spills can have along-term adverse effect. Large spills very unlikely but potentially very damaging to a large area. Small spills much more likely, but much less damaging to a smaller area.	
WILDLIFE	Georgetown area provides an important habitat for a rich variety of wildlife species.	No impact; but future base condition may change significantly due to other developments.	Compliance with NPDES permit should prevent unacceptable impacts due to normal operation. Spills can have a long-term adverse impact. Large spills very unlikely but potentially very damaging to a large area. Small spills much more likely, but much less damaging to a smaller area.		Compliance with NPDES permit should prevent unacceptable impacts due to normal operation. Spills can have a long-term adverse impact. Large spills very unlikely but potentially very damaging to a large area. Small spills much more likely, but much less damaging to a smaller area.	Compliance with NPDES permit should prevent unacceptable impacts due to normal operation. Spills can have a long-term adverse impact. Large spills very unlikely but potentially very damaging to a large area. Small spills much more likely but much less damaging to a smaller area.	
FISHERY	Winyah Bay has high habitat value. Lower Sampit River habitat is lower in value.	No impact; but future base condition may change significantly in response to other developments.	Compliance with NPDES permit should prevent unacceptable impacts due to normal operation. Spills can have a long-term adverse impact. Large spills very unlikely but potentially very damaging to a large area. Small spills much more likely, but much less damaging to a smaller area.		Compliance with NPDES permit should prevent unacceptable impacts due to normal operation. Spills can have a long-term adverse impact. Large spills very unlikely but potentially very damaging to a large area. Small spills much more likely, but much less damaging to a smaller area.	Compliance with NPDES permit should prevent unacceptable impacts due to normal operation. Spills can have a long-term adverse impact. Large spills very unlikely but potentially very damaging to a large area. Small spills much more likely, but much less damaging to a smaller area	
ENDANGERED SPECIES	18 endangered species occur in the vicinity of Winyah Bay. There is no critical habitat.	No impact; but future base condition may change significantly in response to other developments.	Compliance with NPDES permit should prevent unacceptable impacts due to normal operation. Spills can have a long-term adverse impact. Large spills very unlikely but potentially very damaging to a large area. Small spills much more likely, but much less damaging to a smaller area.		Compliance with NPDES permit should prevent unacceptable impacts due to normal operation. Spills can have a long-term adverse impact. Large spills very unlikely but potentially very damaging to a large area. Small spills much more likely, but much less damaging to a smaller area	Compliance with NPDES permit should prevent unacceptable impacts due to normal operation. Spills can have a long-term adverse impact. Large spills very unlikely but potentially very damaging to a large area. Small spills much more likely, but much less damaging to a smaller area.	
SOCIO ECONOMIC	Georgetown County is one of the most economically depressed counties in South Carolina.	No impact; but future base condition may change significantly due to other developments.	Major increase in economic base; an increase in highway traffic.		Major increase in economic base; an increase in highway traffic.	Major increase in economic base; an increase in highway traffic.	
CULTURAL RESOURCES	Georgetown has a rich cultural heritage especially in the Winyah Bay area.	No impact; but future base condition may change significantly due to other developments.	No impact.		No specific refinery site evaluated at Charleston.	Evaluation at any unspecified site is impractical.	
GROUND WATER	Georgetown has abundant ground water resources.	No impact; but future base condition may change significantly due to other developments.	No impact from waste discharge; large spills unlikely but could infiltrate aquifers, especially shallow ones.		No specific refinery site evaluated at Charleston.	Evaluation at any unspecified site is impractical.	



The proposed refinery site is located approximately 4 km (2.5 mi) west of Georgetown, South Carolina, and south of the Sampit River. The site is located within the Sampit River watershead, close to Turkey Creek, Pennyroyal Creek, and their confluence with the Sampit River.

B. Air Quality

1. Existing Conditions

a. Applicable Regulations. The Federal Clean Air Act and Amendments require the establishment of ambient air quality standards. As a result of ambient pollutant levels and the adverse effects of these pollutants, the EPA promulgated the National Ambient Air Quality Standards (NAAQS). As mandated by the Clean Air Act, each state is required to develop a State Implementation Plan (SIP) to ensure the attainment and maintenance of these standards. The national ambient air quality standards and standards of the state of South Carolina are presented in Table VI.B-1.

The NAAQS have two levels of attainment, the national primary and secondary standards. The primary standards have been set to protect the public health; the secondary standards have been set to protect the public welfare. In many cases, the primary and seconday standards are the same. In all cases, the South Carolina Ambient Air Quality Standards (SCAAQS) are as strict as or more restrictive than the national primary standards. South Carolina also has air quality standards for non-methane hydrocarbons and gaseous fluorides that are not included in the NAAQS.

The Clean Air Act also required the establishment of Standards of Performance for New Stationary Sources of air pollution. Commonly referred to as New Source Performance Standards (NSPS), the regulations have focused on large sources of particulate matter, nitrogen oxides, and sulfur dioxide. Recently, a number of standards have been set for sources that emit volatile organic compounds.

The proposed Georgetown Refinery would be directly affected by 40 CFR 60 (NSPS) Subpart J - Petroleum Refineries, Subpart Ka - Storage Vessels for Petroleum Liquids Constructed After 18 May 1978, and Subpart xx - Performance for Bulk Gasoline Terminals. Table VI.B-2 summarizes these standards. Individual equipment and processes within the proposed facility also may be regulated under the NSPS regulations. Once final design has been completed, CRDC would be required to demonstrate that the equipment and processes used at the facility meet all applicable regulations.

In the <u>Federal Register</u> of 4 January 1983, 48 FR 279, the EPA proposed Subpart GGG; VOC Fugitive Emission Sources; Petroleum Refineries. The proposed standards would require a leak detection and repair program, specify certain equipment to reduce VOC emissions, and allow no detectable emissions from pressure relief devices under normal operations. According to EPA's office of Air Quality Standards and Planning, these proposed rules are expected to be promulgated in 1984.

Also required under the Clean Air Act is the establishment of the National Emissions Standards for Hazardous Air Pollutants (NESHAPS). The purpose of these standards is to limit the emissions of certain hazardous pollutants from specific source categories. The pollutants that are regulated have been shown to cause or contribute to increased mortality or serious illness. Compounds presently regulated under the program include asbestos, beryllium, mercury and vinyl chloride. A number of emission standards for other compounds have been proposed.

A proposed standard that may pertain to the proposed refinery would regulate fugitive emissions of benzene from the petroleum refining industry. This proposed rule is slated for promulgation in 1984.

TABLE VI.B-1

COMPARISON OF STATE AND NATIONAL
AMBIENT AIR QUALITY STANDARDS [1,2,3]

Pollutant	Measuring Interval	National Standards Primary	National Standards Secondary	South Carolina Standards
Sulfur Dioxide	3 hour[4]	-	1300	1300
	24 hour[4]	365	-	365
	annual	80	-	80
Suspended Particulates	24 hour	260	150	250
	annual G.M.[5]	75	60	60
Carbon Monoxide[6]	1 hour	40	40	40
	8 hour	10	10	10
Ozone	1 hour[7]	235	235	235
Nitrogen Dioxide	annual	100	100	100
Lead	Calendar quarterly mean	1.5	1.5	1.5
Non-Methane Hydrocarbons	annual	-	-	160
Gaseous Fluorides (as HF)	12 hour	-	-	3.7
	24 hour	-	-	2.9
	1 week	-	-	1.6
	1 month	-	-	0.8

[1] Micrograms per cubic meter except for carbon monoxide.

[2] Arithmetic average except in case of suspended particulates.

[3] At 25°C and 760 mm Hg.

[4] Not to be exceeded more than once a year.

[5] Geometric mean.

[6] Milligrams per cubic meter.

[7] Not to be exceeded more than one day per year.

TABLE VI.B-2

STANDARDS OF PERFORMANCE FOR NEW STATIONARY SOURCES
OF AIR POLLUTION AFFECTING THE GEORGETOWN REFINERY

Source Category	Affected Facility	Pollutant	Emission Level	Monitoring Requirement
Subpart J: Petroleum refineries	Catalytic cracker (with incinerator or waste heat boiler)	Particulate	1.0 lb/1000 lb (1.0 kg/1000 kg)	No requirement
			Additional 0.10 lb/106 BTU (43.0 g/MJ)	No requirement
		Opacity	30%; 6 min, exemption	Continuous
		CO	0.05%	Continuous
	Fuel gas	SO_2	Equal to or less than the level emitted by combustion of a fuel gas with H_2S content of 0.10 gr H_2S/dscf or 230 gm/dscm	Continuous
	Claus sulfur recovery plants >20 LTD/day	SO_2	0.025% by volume of SO_2 with oxidation or reduction and incineration; 0.030% by volume of reduced sulfur compounds and 0.001% by volume of H_2S with reduction only	Continuous
	Catalyst regenerator[1]	SO_x	9.8 kg/1000 kg coke burn-off	
Subpart Ka: Storage vessels for petroleum liquids constructed after May 18, 1978	Storage tanks >40,000 gal. capacity (151,416 liters)	Volatile organic compounds (VOC)	Vapor pressure 1.5-11.1 psia (10.3-76.6 kPa), equip with floating roof or fixed roof with internal floating cover (both must meet specifications) or vapor recovery and disposal system reducing emissions at least 95%	No requirement
			Vapor pressure >11.1 psia (76.6 kPa), equip with vapor recovery and disposal system reducing emissions at least 95%	No requirement Type of liquid, period of storage, and maximum vapor pressure.
Subpart xx: Performance for bulk gasoline terminals	Total of all loading racks which deliver liquid product into gasoline tank trucks	Volatile organic compounds (VOC)	Emissions to the atmosphere from the vapor collection system due to the loading of liquid product into tank trucks are not to exceed 35 mg VOC per liter of product loaded	No requirement Tank truck vapor tightness documentation

[1] Applicable portion of proposed amendment to 40 CFR Part 60, Subpart J

SOURCES: Pahl, 1983; EPA Regulations on Standards of Performance for New Stationary Sources;
Federal Register, Volume 49 of January 17, 1984 (40 FR 2072);
Federal Register, Volume 48 of December 22, 1983 (40 FR 56580);
Federal Register, Volume 48 of August 18, 1983 (40 FR 37578).

Revised 1-12-84

The Code of Federal Regulations (CFR) contains regulations designed to prevent the significant deterioration of air quality in those areas of the country where the ambient air quality is better than the minimum levels required to meet NAAQS. It is the intent of the Prevention of Significant Deterioration (PSD) regulations to ensure that air quality does not significantly deteriorate, while maintaining a margin for future industrial growth.

All regions within the United States have been classified as one of the following: 1) non-attainment (not meeting NAAQS for one or more pollutants); 2) attainment (meeting all applicable NAAQS); or 3) unclassifiable (those areas where data are not available to determine attainment or non-attainment). Attainment and unclassifiable areas are further defined as PSD areas and are subject to the PSD regulations. PSD areas are further classified as either Class I, Class II, or Class III areas, with each area having different allowable incremental increases in pollutant concentrations. The allowable PSD increments (allowable increases in pollutant concentrations over baseline values) are summarized in Table VI.B-3.

b. Local Climatology and Meteorology. The climate of the Georgetown area is temperate. Because of the area's proximity to the ocean, a considerable marine influence is noticeable. This results in temperatures that are generally 5.5° to 8.2°C (10° to 15°F) warmer than more inland areas during times of minimum winter temperatures and generally 1.6°C (3°F) cooler during times of maximum temperatures.

Summers are warm, humid, and the rainiest of the seasons, with 35 percent of the annual rainfall. Precipitation is generally in the form of showers or thundershowers with occasional tropical storms producing variable amounts of rainfall over scattered areas. Late summer and early fall are periods of maximum threat from hurricanes to the South Carolina coast. The fall seasons have mostly sunny weather with rare extremes of temperatures. Winters are mild with a more uniform type of precipitation, although thundershowers have occurred. The highest probability of occurrence for snow flurries exists during January. Spring in the Georgetown area is the season most likely to have severe local storms and rapid changes in the weather. March through May accounts for 21 percent of the annual precipitation (NOAA, 1982).

In general, ground-level concentrations of emitted pollutants within any area vary greatly depending on atmospheric conditions of wind speed, wind direction and atmospheric stability. The local meteorology of an area is very important in determining the dispersion of pollutants and their impact on the environment. Meteorological data available from the National Climatic Center for the area around Georgetown consist of data collected at Charleston, South Carolina and at the Air Force base in Myrtle Beach, South Carolina. Meteorological data for Georgetown were not available. Myrtle Beach is approximately 53 kilometers (33 miles) northeast of Georgetown. Charleston is approximately 80 kilometers (50 miles) southwest of Georgetown.

Figure VI.B-1 represents the Myrtle Beach and Charleston meteorological data in the form of wind roses. The predominant wind patterns are from the north and south with sea breezes evident by strong east and west components. The Myrtle Beach data show high percentages for stable conditions and calm winds. The large difference in the percentage of calm conditions at the two locations may be attributed to Charleston's urban characteristics with associated heat-island effects (heat absorption by concrete and other building materials, and subsequent radiation and convection causing low velocity wind generation).

TABLE VI.B-3

SOUTH CAROLINA DEPARTMENT OF HEALTH AND ENVIRONMENTAL CONTROL
ALLOWABLE INCREASES IN POLLUTANT CONCENTRATIONS OVER BASELINE VALUES

Pollutant	Measuring Interval	Micrograms Per Cubic Meter
Part A. Ambient air increments. In areas designated as Class I, II or III, increases in pollutant concentration over the baseline concentration shall be limited to the following:		
CLASS I		
Particulate matter	Annual geometric mean	5
	24-hour maximum	10
Sulfur dioxide	Annual arithmetic mean	2
	24-hour maximum	5
	3-hr maximum	25
CLASS II		
Particulate matter	Annual geometric mean	19
	24-hour maximum	37
Sulfur dioxide	Annual arithmetic mean	20
	24-hour maximum	91
	3-hr maximum	512
CLASS III		
Particulate matter	Annual geometric mean	37
	24-hour maximum	75
Sulfur dioxide	Annual arithmetic mean	40
	24-hour maximum	182
	3-hr maximum	700

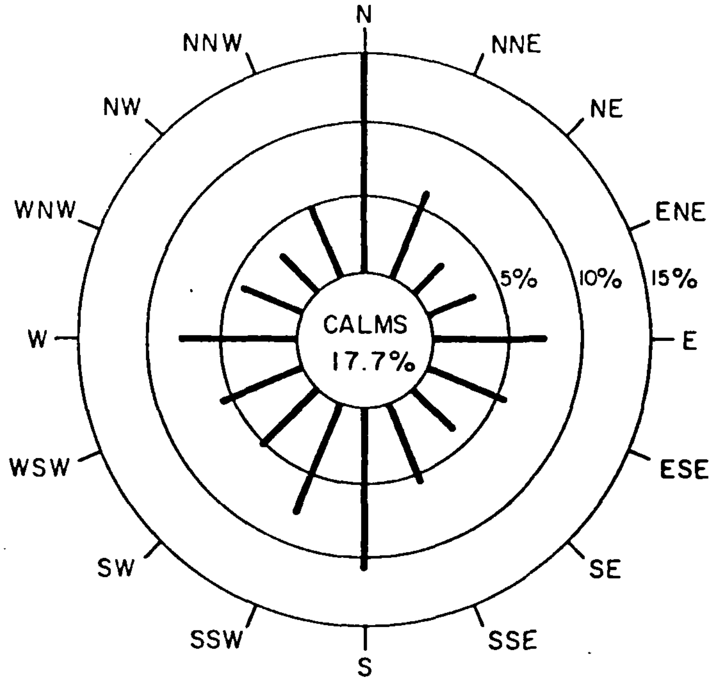
For any period other than an annual period, the applicable maximum allowable increase may be exceeded during one such period per year at any one location.

Part B. Ambient air ceilings. No concentration of a pollutant shall exceed:

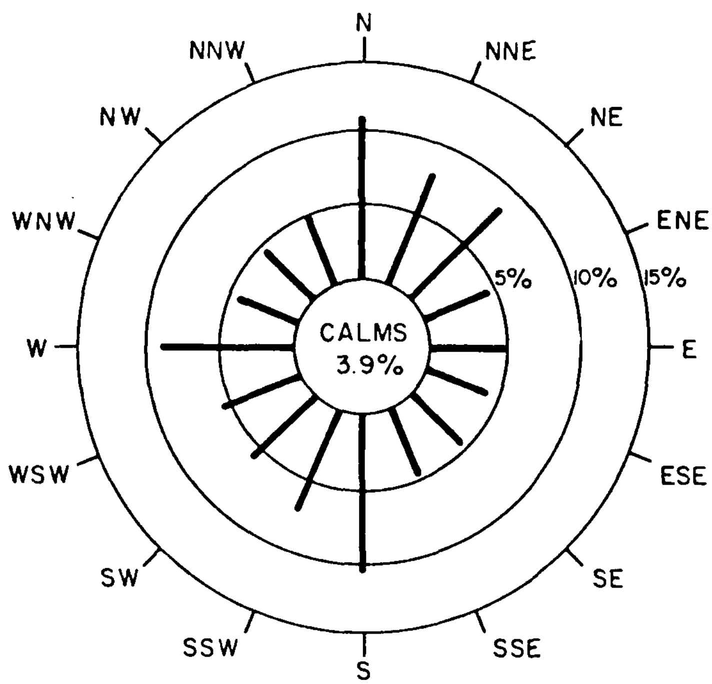
1) The concentration permitted under the national secondary ambient air quality standard, or

2) The concentration permitted under the national primary ambient air quality standard, whichever concentration is lowest for the pollutant for a period of exposure.

SOURCE: South Carolina Department of Health and Environmental Control, n.d.a.



a. WIND ROSE
MYTRLE BEACH A.F.B.
1970



b. WIND ROSE
CHARLESTON
1968 - 1972

Figure VI.B-1. Wind Patterns Recorded Near Georgetown, SC

SOURCE: NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, n.d.

Atmospheric stability is important in determining how quickly and effectively pollutants are mixed and dispersed in the air. The vertical motion of air pockets determines the mixing ability of the atmosphere. This vertical motion is determined by measuring changes in air temperature with atmospheric height. Atmospheric lapse rate is the rate at which temperature changes with height. Lapse rates greater than the standard dry adiabatic lapse rate of -3°C per 305 m (-5.4°F per 1000 ft) of altitude indicate stable conditions; lapse rates less than the standard rate indicate unstable conditions.

Air temperature is influenced by the amount of solar radiation reaching the ground. Solar radiation heats the ground, which then heats the lower layer of air causing the warmer air to rise and the colder air above to sink (vertical mixing).

The Pasquill Stability classification is a system that somewhat quantifies atmospheric stability based on net radiation and horizontal wind speed. Table VI.B-4 lists the five stability classifications reported in the Myrtle Beach meteorological data. Stable conditions usually occur during the night and break up in the late morning. South Carolina and Georgia experience the highest frequencies of stagnant air masses (stable conditions) in the eastern part of the United States (DHEC, 1982).

c. Air Quality Monitoring Data. The South Carolina Ambient Air Monitoring Network consists of three types of monitoring stations: State and Local Air Monitoring Stations (SLAMS); National Air Monitoring Stations (NAMS); and Special Purpose Monitors (SAM). The statewide network provides air quality data to establish background levels of pollutants, determine trends, and to determine compliance with regulations.

The Bureau of Air Quality Control publishes an annual report in July of each year summarizing the data collected and the significant events of the preceding calendar-year. A complete report of annual data is published on a calendar year basis and is titled "Air Pollution Measurements of the South Carolina Air Quality Surveillance Network."

The proposed refinery would be located in the Air Quality Control Region #204, which is composed of Williamsburg, Horry, and Georgetown Counties. There are seven monitoring stations located in this control region, four of which are located in Georgetown County.

Total suspended particulate (TSP) data are collected at three of the monitoring stations. These stations are located at: the Georgetown County Health Department, the Georgetown Howard High School, and the Georgetown Maryville Power Substation. High-volume sampling data collected at these sites from January through December of 1982 are summarized in Table VI.B-5.

South Carolina's air quality standard for TSP is 60 $\mu g/m^3$ annual geometric mean (AGM). A maximum of 250 $\mu g/m^3$, averaged over a 24-hour period, must not be exceeded more than once per year. The standard of 60 $\mu g/m^3$ AGM was last exceeded in 1981. Figure VI.B-2 presents the annual geometric means determined for the three monitoring sites from 1973 to 1982.

The fourth monitoring station is located at the site of Georgetown's water tank. Data are collected for oxides of nitrogen (NO_x) and sulfur dioxide (SO_2). Of the data collected for NO_x, an arithmetic mean of 28 $\mu g/m^3$ was obtained for the year 1982. The ambient air quality standard for NO_x is 100 $\mu g/m^3$ for an annual arithmetic mean (AAM). Sulfur dioxide data, collected at the water tank during 1982,

TABLE VI.B-4

ANNUAL PERCENTAGE OF ATMOSPHERIC
STABILITY AND CALM WINDS
MYRTLE BEACH, SOUTH CAROLINA, 1970

Stability Class	General Definition	Annual Percentage	Percentage Calm Winds
A	Extremely Unstable	1.2	0.1
B	Unstable	11.1	0.7
C	Slightly Unstable	15.1	0.5
D	Neutral	27.8	1.2
E	Slightly to Extremely Stable	44.8	15.2

TABLE VI.B-5

TOTAL SUSPENDED PARTICULATES ($\mu g/m^3$)
GEORGETOWN COUNTY, SOUTH CAROLINA, 1982

Location	Number Observed	Concentrations Maximum	Concentrations Minimum	Annual Geometric Mean
County Health Dept.	59	120	10	49
Howard High School	54	131	9	50
Power Substation	59	51	5	23

SOURCE: DHEC, 1982.

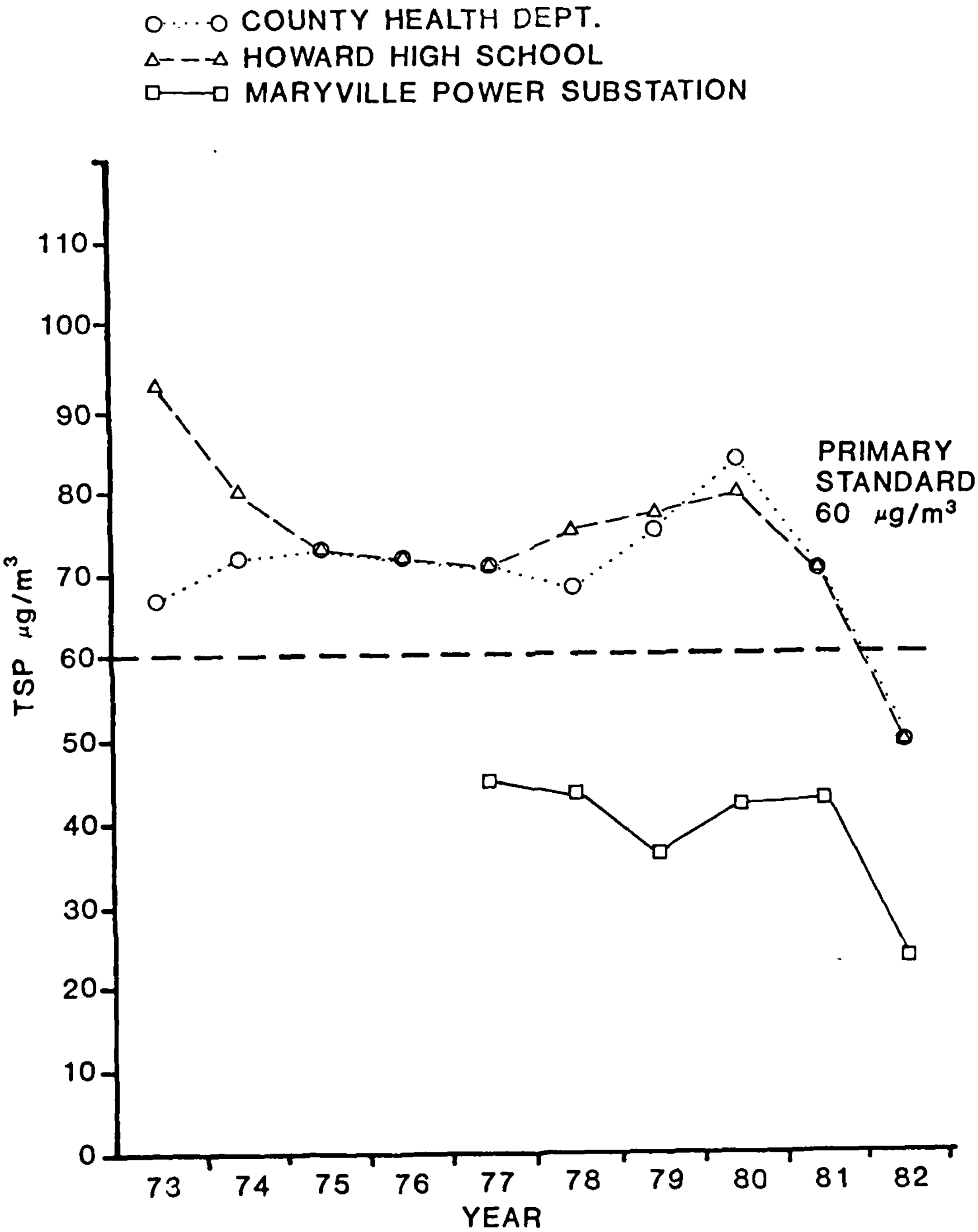


Figure VI.B-2. Total Suspended Particulates, Annual Geometric Means, Georgetown County, South Carolina, 1973-1982.

showed a 9 $\mu g/m^3$ AAM; the standard is 80 $\mu g/m^3$ AAM. The highest 24-hour average SO_2 concentration was 150 $\mu g/m^3$; the standard is 365 $\mu g/m^3$, not to be exceeded more than once per year. The highest 3-hour average monitored was 514 $\mu g/m^3$; the standard is 1300 $\mu g/m^3$ for a 3-hour average, not to be exceeded more than one day per year.

Ozone is monitored at the Hickory Grove Site in Horry County. During the sampling period of April through October of 1982, the highest 1-hour average recorded was 0.099 ppm or 194 $\mu g/m^3$. The ambient air quality standard is 0.12 ppm or 235 $\mu g/m^3$, a 1-hour average not to be exceeded more than one day per year. This site is the only site monitoring ozone within the Georgetown air quality control region. The remaining two sites in the control region, located at Conway and Myrtle Beach in Horry County, only monitor suspended particulates.

Other pollutants for which ambient air quality standards exist are carbon monoxide (CO), non-methane hydrocarbons (HC), gaseous fluorides (HF), and lead (Pb). Monitoring data for these air pollutants are not collected in this air quality control region.

d. Current Area Air Quality Designations. Areas where monitoring data or computer modeling show pollutant concentrations in excess of the ambient air quality standards are classified as non-attainment areas for that pollutant.

At the beginning of 1983, there were three areas of non-attainment for carbon monoxide in South Carolina: Columbia, Greenville, and Charleston Counties. Of the three areas, only the Greenville area has shown concentrations in excess of the primary carbon monoxide standard in the past two years. Redesignation to attainment area is expected for the Columbia and Charleston areas. The main strategy to bring about attainment of the carbon monoxide standards has been auto emissions controls.

South Carolina had three areas designated as being in non-attainment for ozone at the beginning of 1983: Richland-Lexington Counties, Charleston-Berkeley Counties, and York County. South Carolina's strategy to bring about attainment for ozone is to implement the Volatile Organic Compound (VOC) Regulations. VOC emissions are known to be part of a complex atmospheric reaction that results in high concentrations of ozone. Through the control of VOC emissions, reductions in ozone concentrations are expected. As of 1 November 1983 the Federal Register indicated Charleston-Berkeley Counties remained designated as non-attainment areas for the ozone standard (48 FR 50316). All of South Carolina is in attainment for sulfur dioxide, nitrogen oxides, and lead.

Areas of non-attainment for total suspended particulates (TSP) in South Carolina during 1983 were within North Charleston (near Pittsburg Avenue and Meeting Street), and a portion of downtown Georgetown. The monitoring data for these areas have shown continuing improvement. Requests for a change of status have been submitted to USEPA. In the 1 November 1983 Federal Register, 48 FR 50316, the USEPA amended the TSP attainment status table for South Carolina by removing the entry for the downtown Georgetown area and designating Georgetown County TSP status as "Better than National Standards" (40 CFR Sec. 81.341). No action was taken on the redesignation of the North Charleston area.

The area where the proposed refinery is located is classified as attainment for all of the pollutants that have NAAQS.

e. Area Air Emissions Inventory. Under the South Carolina Department of Health and Environmental Control, Air Pollution Control Regulations, R. 61-62.1, Section III - Emissions Inventory, an emissions inventory for all major plants must be reviewed annually. These inventories have been designed to locate air pollution sources, define the types and sizes of sources, define the types and amounts of emissions, determine the frequency, duration and relative contributions of emissions to pollution problems, and to determine the adequacy of regulations and standards. Table VI.B-6 lists the sources of air emissions and quantities of major emissions in Georgetown County, South Carolina.

f. Area Sites Sensitive to Air Quality. Sites within Georgetown County that could be sensitive to air quality effects resulting from the location of a new major emission source within the area include the following:

- Georgetown County (all of the county is in attainment of the NAAQS and is designated a Class II Air Quality Area);

- Cape Romain National Wildlife Refuge (Figure VII.B-17; all of South Carolina is designated as a Class II Air Quality Area for PSD except for the Cape Romain National Wildlife Refuge, which is a Class I area; the refuge contains 22,285 hectares [55,066 acres] of tidal creeks, bays, barrier islands and marshlands and is located 27 km [17 mi] south of the proposed refinery site; sources located in Berkeley County have consumed the allowable sulfur dioxide increment for the wildlife refuge);

- Hobcaw Barony (Figure VI.C-2; 7,082 hectares [17,500 acres] of beach, forest and marshlands located to the east of the proposed refinery and bordering Winyah Bay and the Atlantic Ocean; it includes: the Belle W. Baruch Forest Science Institute of Clemson University; the Baruch Marine Field Laboratory of the University of South Carolina, located on North Inlet Estuary, the only marsh-estuarine system selected by the National Science Foundation to participate in the nation-wide Long-term Ecological Research Program; Pumpkinseed Island, one of the most important rookeries in South Carolina for White Ibis, Great and Snowy Egrets and many varieties of herons);

- State Game Management Areas (near the proposed refinery are the Waker Farm, Wildhorse, Kilsock, Santee Delta [Figure VII.B-17], Samworth and the Santee Coastal Reserve [Figure VI.C-2] game management areas);

- Tom Yawkey Wildlife Center (Figure VI.C-2; 7,222 hectares [17,845 acres] of high land and marsh on North, South and Cat Islands, with a designated wilderness area on North Island, a waterfowl protection and feeding area on South Island and the remainder designated as a wildlife refuge area);

- Francis Marion National Forest (Figure VII.B-17; located in Berkeley and Charleston Counties approximately 18 km [11 mi] southeast of the proposed refinery and containing 100,937 hectares [249,412 acres], this national forest includes Hampton Plantation State Historical Park, scenic and natural areas in Little Wambaw Swamp, and Guilliard Lake, a wilderness study area in Wambaw Swamp, the archaeological area of Sewee Indian Shell Mound, and various other special interest areas).

TABLE VI.B-6

SOURCES OF AIR POLLUTION
AND EMISSIONS TOTALS
GEORGETOWN COUNTY, SOUTH CAROLINA

Establishment Name	Location
M and T Chemicals	Andrews
International Paper Company	Georgetown
Georgetown Steel Corporation	Georgetown
Santee Cooper Winyah Power Plant	Georgetown
Koppers Plant	Georgetown
Sampit Lumber Mill	Georgetown
American Cyanamid Company	Georgetown
Winn-Dixie Food Store	Georgetown
Piggly-Wiggly Store	Georgetown
Oneita Knitting Company	Andrews
Martin Marietta Company	Jamestown

Source Emissions Totals (Tons/Year)
Georgetown County, South Carolina

Pollutant	Emission Total	
	Metric Tons/Year	(Tons/Year)
TSP	1,521	(1,675)
SO_2	46,884	(51,646)
HC	478	(526)
CO	1,387	(1,528)
NO_x	17,878	(19,694)

SOURCE: South Carolina Department of Health and Environmental Control n.d.b.

2. Future Air Quality Conditions Without the Refinery

The air quality in the area surrounding Georgetown is presently meeting all NAAQS. All parts of the county are subject to PSD regulations. These regulations set maximum ambient air pollutant concentrations. These concentrations vary with location, but in all cases are less than or equal to the NAAQS. As long as the PSD regulations are enforced, the air quality of the Georgetown area should remain below the NAAQS.

C. Surface Water Characteristics

1. Introduction

The major surface waters that may be impacted by the development of a refinery in Georgetown, South Carolina include the Sampit River, Winyah Bay, and to a lesser extent, the lower Pee Dee and Waccamaw River systems, and adjacent Atlantic coastal areas. The Sampit River is a tidally-influenced coastal river with a relatively low flow rate. It would directly receive wastewater discharged from the plant and would be impacted by any spills in Georgetown Harbor resulting from oil transport. Winyah Bay is a large estuarine system that extends about 21 km (13 mi) from Georgetown to the Atlantic Ocean. Winyah Bay receives flow from the Sampit, Black, Pee Dee and Waccamaw Rivers at the upper end and discharges to the Atlantic Ocean through a narrow pass between North and South Islands. Winyah Bay would receive oil or other wastes spilled in or discharged to the Sampit River or spilled during shipment of oil from the Atlantic Ocean through Winyah Bay or the Intracoastal Waterway to the Georgetown docking facilities. These water bodies are shown in Figure VI.C-1, a mosaic of color photographs from the National High Altitude Photography Program (USGS, 1983). A companion map, Figure VI.C-2, gives geographical place names as well as locations of wildlife preserves, research centers and other sites referred to in the text. Additional place names are shown in Figure VII.B-17 in Section VII of this document.

2. Federal, State and Local Regulations

Various federal, state and local regulations are applicable to the maintenance of surface water quality, the regulation of wastewater discharges and procedures for spill control. Such regulations will be discussed in following sections and a detailed presentation will be made of the existing surface water characteristics of the Sampit River, Winyah Bay and related water bodies.

a. Water Quality Standards. The Federal Clean Water Act of 1977 provides the authoritative basis for federal water quality criteria. When water quality criteria are adopted by a state for specific water uses, the criteria become legally enforceable water quality standards.

Under the South Carolina Pollution Control Act (48-1-10 [et seq] SC Code of Laws), the Department of Health and Environmental Control is charged with enforcement of the provisions of the law, including standards of water quality. This was accomplished by promulgation of Regulation 61-68, Water Classification Standards System, effective 24 July 1981. In South Carolina, the Department of Health and Environmental Control (DHEC) has established four specific water quality classifications for tidal waters: SAA - Outstanding Resource Waters; SA -Shellfishing Waters; SB - Primary Recreation Waters; and SC - Secondary Recreation and Fishing Waters. The water quality standards promote protection of public health and welfare, promote maintenance and enhancement of water quality, specify appropriate water uses to be achieved and protected, and specify the appropriate water quality criteria (such as dissolved oxygen, fecal-coliform bacteria, temperature, etc.) necessary to support designated uses. All waters must be free from debris, settleable solids, and toxic or corrosive substances while meeting maximum temperature requirements. DHEC does recognize that some waters violate standards under natural conditions; for such waters standards are usually developed independently.

Figure VI.C-1. Aerial photograph of the Winyah Bay area.

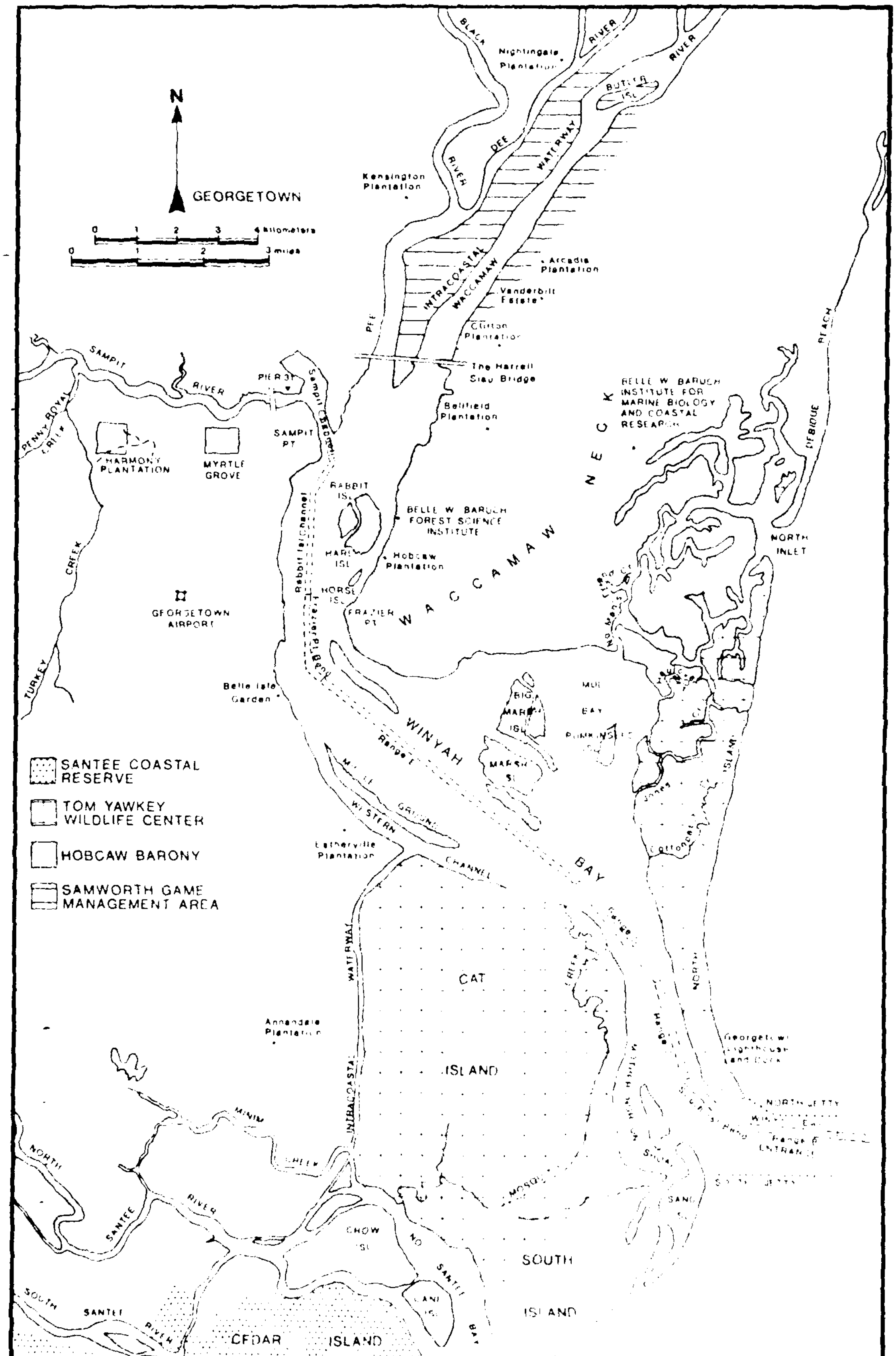


Figure VI.C-2. Geographical and geopolitical designations ...

Water quality standards serve as a basis for determining Natural Pollutant Discharge Elimination System (NPDES) effluent limitations for point-sorce discharges. They also serve to evaluate Best Management Practices (BMPs) for control of nonpoint sources of pollution and are used as a basis for judging other water quality programs, including water quality inventories, control of toxic substances, thermal discharges, stormwater runoff and dredge and fill activities.

b. Waste Discharge Regulations. Section 402 of the Federal Water Pollution Control Act established the National Pollutant Discharge Elimination System (NPDES) for regulating point-source wastewater discharges. South Carolina DHEC has the authority, with review authority maintained by USEPA-Region IV, to grant or deny a wastewater discharge to any waters within South Carolina. The approved discharge permit, based on USEPA guidelines, should include effluent limits, a schedule for complying with effluent limits, monitoring and reporting methods, and sludge disposal plans. NPDES permit applications must include a list of all pollutants, average and maximum quantities of wastewater, frequency of discharge and specification of the proposed discharge location.

Based on Federal NPDES guidelines, following approval of the NPDES permit application, the discharger must provide to South Carolina DHEC a schedule for commencing discharge, outfall and interceptor locations and design plans, projected outfall and interceptor installation procedures and treatment start-up plans and proposed monitoring procedures. In addition, South Carolina DHEC can periodically inspect discharge facilities to determine how well permit requirements are being met.

South Carolina DHEC also can choose to include special discharge permit requirements when they are needed to protect environmental quality. Examples of special requirements are:

- variations in discharge quality requirements from season to season;
- special wastewater treatment operation or maintenance procedures;
- requirements conditional upon future events;
- special runoff control techniques; and
- monitoring within the Sampit River.

Discharge permit requirements for new oil refinery discharges are subject to New Source Performance Standards (NSPS) that are based on the best available demonstrated technology as defined in the preamble to 40 CFR Part 419 (Final USEPA rule dated 18 October 1982). Whatever level of wastewater treatment can be provided and efficiently operated establishes many of the discharge permit requirements independent of water uses established for downstream waters, such as the Sampit River and Winyah Bay. NSPS standards are based on recycling and reuse of wastes, which would reduce the mass of pollutants discharged by 25 to 50 percent beyond treatment levels obtainable with the Best Practicable Control Technology Currently Available (BPT) (40 CFR Part 419; 18 October 1982). A number of toxic pollutants within refinery wastewaters are not regulated by treatment standards as discussed in Section B of Chapter VII in this Draft EIS. Limitations for stormwater runoff are not in effect on the federal level, but chemical oxygen demand (COD) standards for ballast waters are in effect, based on "best available technology economically achievable" (40 CFR Part 419). Once-through cooling waters can be discharged as long as total organic carbon concentrations do not exceed 5 mg/l.

A draft NPDES discharge permit (NPDES No. SC0037311) was prepared by South Carolina DHEC in 1981 for the proposed CRDC refinery. This was transmitted to the applicant on 16 September 1981 (Gross, 1981) with the requirement that the applicant respond within 30 days. Since no response was ever received from the applicant, the applicability of discharge limitations in the draft permit was automatically canceled. Furthermore, new federal effluent limitation guidelines for petroleum refining point source category were published the following year (40 CFR Part 419, Final USEPA Rule, 18 October 1982). It is of interest that the draft NPDES permit presented discharge limitations that were uniformly more stringent than the federal effluent limitations published in October 1982. If the CRDC applicant should reapply, however, a new NPDES permit would be written with discharge limitations based upon the more restrictive of federal or state guidelines, including the 1982 effluent limitation guidelines and the USEPA Water Quality Criteria (1980) (Solley, personal communication, [illegible]).

The [illegible] standards for the cracking subcategory are appli[illegible]. Table [illegible] lists these effluent standards [illegible] of feedstock and various refinery process capacities [illegible] VI.B of this Draft EIS. Development of the federal [illegible] technologies and recycle-reuse potential independent of [illegible] the waters which receive the treated effluent.

The South Carolina [illegible] has the authority to certify whether permits for wastewater [illegible] contravene the South Carolina Coastal Management P[illegible] cooperates with the Coastal Council by providing them [illegible] necessary for their certification review. The [illegible] concerned with potential impacts on shellfish, recreation[illegible] and critical wildlife habitats.

Enviromental requirements [illegible] solid and hazardous wastes from the proposed refinery are authorized in the [illegible] Conservation and Recovery Act (RCRA). Based on RCRA, [illegible] have the [illegible] hazardous wastes from their generation [illegible] ultimate disposal. Passage of RCRA was prompted largely by concerns with [illegible] groundwater and surface water from lagoons and other waste storage sites. [illegible] considered major generators of hazardous wastes ([illegible], 19[illegible]).

Based on RCRA, hazardous waste disposal permits are required for both storage and disposal of hazardous wastes. Permit applications must include waste composition, quantities, discharge rates and discharge location(s). Waste recycling is encouraged wherever possible. When a permit is obtained, the governing agency has the authority to inspect facilities, access records and obtain samples. The USEPA and other sources have published various documents to assist dischargers with managing solid wastes (USEPA, April 19[illegible]; [illegible], 19[illegible]). In addition, the USEPA (40 CFR Part 264) has issued land treatment, storage and disposal regulations which establish performance standards for hazardous waste landfills, surface impoundments, land treatment units and waste piles.

Hazardous wastes normally generated [illegible] slop oil, coke fines, and sludges from heat exchangers, the oil-water separator, the dissolved air flotation treatment unit, and [illegible] intends to dispose of hazardous solid wastes in a landfill approved [illegible] regulatory agency, such as the landfill operated by [illegible] (Beam, 1981).

TABLE VI.C-1

FEDERAL EFFLUENT LIMITATIONS FOR THE
PROPOSED CAROLINA REFINING AND DISTRIBUTING COMPANY
(CRDC) REFINERY AT GEORGETOWN, SOUTH CAROLINA[1]

Pollutant or Pollutant Property	Effluent Limitations, Kilograms	
	Maximum for any one day	Average of daily values for 30 consecutive days
Five-day Biochemical Oxygen Demand (BOD_5)	104.1	55.6
Total Suspended Solids (TSS)	72.2	46.0
Chemical Oxygen Demand (COD)	754.0	389.8
Oil and Grease	30.7	16.6
Phenolic Compounds	0.76	0.37
Ammonia (as Nitrogen)	120.1	54.9
Sulfide	0.67	0.31
Total Chromium	1.53	0.89
Hexavalent Chromium	0.128	0.056
pH	6.0 to 9.0	6.0 to 9.0

[1]Based on 40 CFR Part 419 (47 FR 46434), Petroleum Refining Point Source Category Effluent Limitations Guidelines, Pretreatment Standards, and New Source Performance Standards, Subpart B - Cracking Subcategory

The USEPA maintains a list of toxic pollutants. Based on the 1977 Federal toxic pollutant list and a 1977 survey of petroleum refineries, 71 toxic pollutants were listed as purchased materials. At least ten percent of the surveyed refineries purchased the following toxic substances: benzene, carbon tetrachloride, 1,1,1-trichloroethane, phenol, toluene, zinc, chromium, copper and lead (USEPA, 1979). The reader is referred to Section B.2.a.(1) of Chapter VII for a listing of pollutants projected to be released from the Georgetown refinery. Many of those pollutants listed are toxic substances.

c. Erosion and Sediment Control. The proposed pipeline under the Sampit River necessitates compliance with the Federal Clean Water Act, Section 404 - Permits for Dredged or Fill Material. Additionally, this project is within the purview of the United States Department of Agriculture Soil Conservation Service guidelines, as well as guidelines and policies of the South Carolina Coastal Management Program. The South Carolina Coastal Council, through passage of the state's Coastal Zone Management Act, is mandated with implementing the program. The state has incorporated relevant Soil Conservation Service guidelines into its sediment and erosion control policies.

The state has developed policies that are specific to energy and energy-related facilities, including oil refineries and petrochemical facilities. Relevant policies are contained in the Guidelines and Policies of the South Carolina Coastal Management Program (SC Coastal Council, 1979). Dredging policies are also included in the coastal management program.

The SC Coastal Council guidelines state that certain considerations will be included in site location, construction and design, where feasible, including buffer strips of natural vegetation and control of storm runoff, soil erosion and accidental placement of sediments in wetland areas.

SC Coastal Council guidelines are also presented for excavation activities for installation of submerged pipelines. These include minimizing excavation activities, using existing rights-of-way wherever feasible, and employing erosion and sediment control techniques.

With regard to dredging, the overall objective of the Council guideline is to keep suspended sediments to a minimum. The use of weirs and silt curtains is appropriate.

d. Spill Control. The Federal Clean Water Act contains a special provision to control the discharge of oil. In addition, this Act calls for the development of a national contingency plan for removal of oil that has been discharged.

The USEPA and Coast Guard are the federal agencies with primary enforcement responsibility for oil pollution prevention. The Coast Guard is generally responsible for regulating the transportation of oil by pipeline or ship and the transfer of oil to or from a ship. Coast Guard regulations concerning oil pollution prevention for marine oil transfer facilities are found in 33 CFR 154. These regulations detail requirements for the type of equipment to be used in transferring oil, facility operating procedures and the preparation and availability of records. Coast Guard regulations concerning the unloading and transfer of oil are found in 33 CFR 155 and 33 CFR 156. These regulations include details on vessel equipment to be utilized, transfer procedures, inspection and testing procedures, notification procedures, and records to be maintained. Regulations found in 33 CFR 157 detail procedures for the protection of the marine environment pertaining to tank vessels

carrying oil in domestic trade. These regulations include requirements for the design of the vessel and equipment utilized, operation of the vessel during the delivery and transfer of the oil, and inspection and approval procedures which the Coast Guard utilizes to enforce these regulations. These regulations apply to both domestic and foreign vessels that enter any U.S. port.

USEPA regulations concerning the preparation and implementation of a Spill Prevention Control and Countermeasure Plan (SPCC) for oil facilities are found in 40 CFR 112. This plan is to be prepared within six months of the date the facility begins operation and shall be implemented as soon as possible, but not later than one year after the facility begins operations. The SPCC Plan also addresses containment and/or diversionary structures or equipment to prevent discharged oil from reaching a navigable water course. In addition, criteria for State, local and regional oil-removal contingency plans appear in 40 CFR 109. Proposed regulation 40 CFR 111 sets forth the procedures for voluntary removal of oil and hazardous substances by the discharger. This proposed regulation contains detailed procedures to follow concerning removal of a spill, mandatory provisions to be adhered to, liability of the discharger, and civil penalties. USEPA regulations contained in 40 CFR 113 and 40 CFR 114 detail the liability limits for small onshore oil storage facilities and the civil penalties for violations of oil pollution prevention regulations.

3. Sampit River

The Sampit River is characterized as a coastal plain stream, meaning that it originates in the coastal plain and flow is dominated by tidal action (Mathews et al., 1980). The river originates in marshes about 19 km (12 mi) or more upstream from its entry into Winyah Bay, near the city of Georgetown, South Carolina.

The lower portion of the Sampit River has been dredged and altered to form Georgetown Harbor and the harbor's turning basin. Past dredging of the lower reaches of the Sampit River increased the depth, resulting in a large increase in sediment deposition. Average annual maintenance dredging for the harbor area exceeds 1.07 million m^3 (37.7 million ft^3; Mathews et al., 1980).

Several industries located in Georgetown and its vicinity discharge wastewaters into the river. These discharges, combined with runoff from marsh and swamp lands adjacent to the river, contribute a chronic load of pollutants to the Sampit River and bottom sediments.

a. Existing Water Uses. The lower Sampit River is used to transport industrial materials and supplies to and from the port of Georgetown. The upper Sampit River is used for recreational fishing. There are no major users of Sampit River water, since municipal water supplies are drawn from wells and large industrial users have access to waters of the Waccamaw, Pee Dee and Black Rivers just north of Georgetown.

The Sampit River holds two classifications under the Water Classification Standards System for the State of South Carolina. The river is Class B from the headwaters to the point of saltwater intrusion. This point varies somewhat with the tides but is generally located above the U.S. Highway 17 bridge (Muga and Smith, 1981). Class B waters are fresh waters considered suitable for secondary contact recreation, for fishing and propagation of fish and other fauna and flora, and as a source for drinking water supply after conventional treatment (DHEC, 1983). Quality standards are as outlined in Table VI.C-2. From the point of saltwater intrusion to Winyah Bay, the Sampit River is Class SC, the lowest standard water

TABLE VI.C-2

QUALITY STANDARDS FOR CLASS B WATERS

Items	Specifications
(1) Garbage, cinders, ashes sludge or other refuse	None allowed.
(2) Treated wastes, toxic wastes, deleterious substances, colored or other wastes except those listed in (1)	None alone or combined if they adversely affect the taste, color, odor or sanitary condition of shellfish for human consumption; or to impair the waters for any other best usage as determined for this class.
(3) Dissolved oxygen	Daily average 5 mg/l or greater with a low of 4 mg/l. Specified waters may have an average of 4 mg/l due to natural conditions.
(4) Coliform bacteria	Not to exceed an MPN total coliform median of 70/100 ml, nor shall more than 10% of the samples exceed an MPN of 230/100 ml. Test using five tube dilution method.
(5) pH	Shall not vary more than ± 0.3 pH unit from that of effluent-free waters in the same geological area having similar total salinity, alkalinity and temperature, but not lower than 6.5 or above 8.5.
(6) Temperature	As prescribed in paragraph 7.c, page 7 of Water Classification Standards System for the State of South Carolina, 1983.

SOURCE: South Carolina Department of Health and Environmental Control, 1983

quality classification. Class SC waters are tidal salt waters suitable for secondary contact recreation, the survival and propagation of marine flora and fauna, and fishing or crabbing, but no commercial harvesting of clams, mussels or oysters (DHEC, 1983). Quality standards for Class SC waters are listed in Table VI.C-3.

b. Sampit River Flow Characteristics. Currents within the Sampit River are influenced greatly by the tidal cycle. Current velocities measured in September 1975 in the center of the river indicate generally equal velocity but opposite direction for currents during the range of tide from high to low (Henningson, Durham and Richardson, 1976). These measurements, taken near the U.S. Highway 17 bridge and near the junction with Pennyroyal Creek, are presented in Table VI.C-4. These values correspond closely to measurements made in July 1976 in a study for the International Paper Company (Lawler, 1976).

Fresh water flow from the Sampit River is generally low, varying seasonally and with the tidal cycle. Volumetric freshwater flow-rate from the Sampit River to Winyah Bay was estimated to be only 1.1 m^3/sec (40 cfs) for the critical lunar tidal period in July 1976 (Lawler, Matuskey and Skelly Engineers, 1977). Other estimates (Henningson, Durham and Richardson, 1976) place the freshwater flow at from 0.5 to 5 m^3/sec (17 to 175 cfs). This indicates that the freshwater input to Winyah Bay from the Sampit River is negligible compared to other river flow rates such as the Pee Dee River, averaging around 510 m^3/sec (18,000 cfs; USGS, 1984), and the Waccamaw River, averaging around 34 m^3/sec (1,200 cfs; Mathews et al., 1980). The major portion of volumetric flow through the lower Sampit River is from tidal mass movement.

c. Dispersion and Flushing Characteristics. The Sampit River can be considered as an estuary with a variable but relatively low level of freshwater inflow. As such, dispersion and flushing characteristics would be related mostly to tidally induced circulation (Najarian et al., 1983). During periods of very low freshwater inflow, most of the river would be considered to be homogenous with respect to density, and therefore little stratification would be expected. During higher levels of freshwater inflow some stratification may occur which will add density currents to the overall model of river circulation. This complex combination of fluid motions makes modeling efforts difficult. Some models have been used, such as the RECEIV model adapted to the Sampit River by the USEPA and modified by the International Paper Company (Lawler, Matuskey and Skelly Engineers, 1977) to model step discharge of paper mill wastewaters. The application of this model to a continuous discharge in the Sampit River may be useful for evaluation of the effects of the proposed refinery discharge.

Some general characteristics of flushing action in the Sampit River can be empirically derived from the results of tracer studies conducted during a period of low freshwater inflow (Johnson, 1978). The study was conducted in April 1977, which corresponded to a period of sparse rainfall. Actual freshwater flow in the Sampit River during this period was unreported, but low flow could be estimated to be less than 1.1 m^3/sec (40 cfs; Lawler, Matuskey and Skelly Engineers, 1977). A rhodamine dye was injected midstream at a point about 4.7 km (2.9 mi) from the mouth of the river, which is approximately 2.4 km (1.5 mi) downstream from the Pennyroyal Creek junction. Channel depths at this point range from 7.6 to 10.7 m (25 to 35 ft). The dye was injected during afternoon low slack tide. The results showed that 90 percent of the dye was flushed out of the river within two weeks and close to 100 percent within 35 days. Dye was flushed into tributary creeks and marshy areas on the incoming tide, resulting in a decrease in mid-stream concentration. This dye would then flow out of the marshes and tributaries during ebb tide and cause a sub-

TABLE VI.C-3

QUALITY STANDARDS FOR CLASS SC WATERS

Items	Specifications
(1) Garbage, cinders, ashes, sludge or other refuse	None allowed
(2) Treated wastes, toxic wastes, deleterious substances, colored or other wastes except those listed in (1)	None alone or combined if: they adversely affect the survival of marine flora or fauna, their culture or propagation, the taste, color, odor or sanitary condition of fish for human consumption; they make waters unsafe or unsuitable for secondary-contact recreation; they impair the waters for any other best usage.
(3) Dissolved oxygen	Not less than 4 mg/l.
(4) Fecal coliform	Not to exceed a geometric mean of 1000/100 ml based on five consecutive samples during any 30-day period; nor exceed 2000/100 ml in more than 20 percent of the samples.
(4) pH	Shall not vary more than ±1.0 pH unit from that of effluent-free waters in the same geological area having a similar total salinity, alkalinity and temperature, but not lower than 6.5 or above 8.5.
(5) Temperature	As prescribed in paragraph 7.C, Page 7 of Water Classification Standards System for the State of South Carolina, 1983.

SOURCE: South Carolina Department of Health and Environmental Control, 1983

TABLE VI.C-4

SAMPIT RIVER WATER VELOCITIES

17 SEPTEMBER 1975

Tide	Speed cm/sec	(ft/sec)	Direction
Center of River near U.S. Highway 17 bridge			
High	41.4	(1.36)	upstream
Mid	50.9	(1.67)	downstream
Low	10.0	(0.33)	downstream
Mid	50.9	(1.67)	upstream
High	15.2	(0.5)	upstream
Center of River near Pennyroyal Creek			
High	15.8	(0.52)	upstream
Mid	30.5	(1.0)	downstream
Low	7.3	(0.24)	downstream
Mid	30.5	(1.0)	upstream
High	11.6	(0.38)	upstream

SOURCE: Henningson, Durham and Richardson, 1976

sequent increase in mid-stream concentration. How much of the dye was retained in the surrounding marshes was not reported. Very little trace of the dye showed up along the Georgetown waterfront. Since peak concentrations were measured 11 km (7 mi) upstream from the mouth of the river on high tide, tidal excursion in the lower Sampit River was estimated to be about 6.4 km (4 mi).

A number of field surveys were conducted on the Sampit River for the IPC (Lawler, 1976) in order to verify use of the RECEIV model. Among the measurements made were a series of drogue surveys conducted in August 1976. Drogues which were released just after high water slack and two hours after high water slack cleared the mouth of the Sampit River prior to reversal in tide, in some cases reaching all the way to the Western Channel. These drogues were released near Whites Creek in the vicinity of the IPC discharge.

A run of the RECEIV model for a fictitious conservative tracer was conducted for IPC based upon field survey data. Results indicated that 60 percent of the tracer injected at high water slack in the vicinity of the actual IPC discharge point would leave the Sampit River prior to the following low water slack, a period of about six hours. However, about half of that amount would be carried back into the Sampit River on the incoming tide.

d. Salinity Profile. The salinity regimes of the Sampit River are a function of the tidal cycle. Intrusion of saline waters upstream into the Sampit River is an important factor when considering the chemical composition of the river waters, the effect of the fresh-saline interface on flocculation of suspended fine sediments and the dispersive water circulation effects caused by density variations in the water body.

During high tides and average or low freshwater inflow from the Pee Dee and Waccamaw Rivers, the saline waters from Winyah Bay may intrude as far upstream as Pennyroyal Creek. Not only does this intrusion carry more saline waters into the Sampit River, but fine silt is also carried that may then flocculate and settle in that portion of the river basin. Assimilation of spilled or discharged oil or other wastes by this sediment may occur and, thus, such pollutants will not be readily flushed from the river.

In addition to tidal movements of saline water into the Sampit River, density currents may occur that could increase the distance of saline water movement upstream. Salinity and density measurements in the Sampit River have shown that the lower river portions may be somewhat stratified, with complete mixing occurring in the vicinity of Pennyroyal Creek (Henningson, Durham and Richardson, 1976; Johnson, 1978).

Under some conditions of high flow from the Pee Dee and Waccamaw Rivers, estimated to occur about 10 percent of the time (Johnson, 1978), saltwater in the northern end of Winyah Bay could be pushed below the entrance to the Sampit River. Under such conditions, fresh water could flow into the Sampit River with high tide. This would create a situation in which no saline interface would exist in the river and dispersion and dilution may vary somewhat from normal conditions.

e. Water Quality. The waters and sediments of the Sampit River are somewhat polluted, mostly as a result of discharges from the City of Georgetown and its associated industries. Organic-laden waters also enter the Sampit River via runoff from surrounding marshes.

Baseline petroleum hydrocarbon measurements were conducted on Sampit River surface waters between October 1981 and November 1982 (Bidleman and Svastits, 1983). The evaluation of the results was that the Sampit River surface waters were relatively clean with respect to petroleum hydrocarbons. Stations well upstream yielded total hydrocarbon levels between 0.46 and 1.0 μg/l by gas chromatography. Locations just downstream of the paper mill yielded 0.73 to 2.0 μg/l over three samples with a fourth measurement at 29.9 μg/l. Sampling near Georgetown Steel revealed levels from 1.1 to 4.5 μg/l and, in the fishing trawler docking area, values ran from 3.1 to 97.5 μg/l. The analysis of hydrocarbons suggests that lubicating oils may be the major constituent with some heavy aromatic compounds present, possibly from urban runoff or atmospheric deposition.

Dissolved-oxygen levels and BOD will vary somewhat with seasonal variations in water temperature, freshwater runoff and salinity. Measurements made by the IPC in July, 1976 in the Sampit River showed levels of BOD_5 at 10.0 mg/l and DO at 5.2 mg/l at a temperature of 24.2°C (Lawler, Matuskey and Skelly Engineers, 1977). Presently measured levels of BODs are much lower, averaging 2.0 mg/l or less, which indicates significant improvement in this parameter. Annual average values for a number of water-quality parameters for two sampling stations on the Sampit River are given in Tables VI.C-5 and VI.C-6.

The water quality assessment by South Carolina Department of Health and Environmental Control (SCDHEC) for water years 1979 through 1981 characterized the Sampit River as "fair" overall (Knox and Turner, 1982). The characteristics of temperature, oxygen, pH, bacteria, aesthetics and solids were considered "good", while nutrients and inorganic toxicants were considered "fair". An evaluation of "good" indicates that the water quality parameters generally meet or exceed the state standards, while "fair" indicates these standards may or may not always be met.

Observation of the more current water quality data shown in Tables VI.C-5 and VI.C-6 reveals that many characteristics have remained relatively stable while some nutrient level indicators show an improvement trend.

f. Existing Pollutant Sources. Many point and non-point pollutant sources impact the water quality of the Sampit River. The major sources include non-point natural pollution from runoff and point sources such as Georgetown Steel, International Paper Company, and the municipal wastewater treatment facility. On a smaller scale, numerous marinas, pleasure boats, fishing trawlers and other small industries provide sources for some pollution. Table VI.C-7 lists some reported pollutant levels or levels authorized by NPDES permit for the major industrial sources, estimated pollutant levels for the proposed refinery, plus an estimate of BOD for natural swamp water input to the Sampit River. As can be noted, total mass discharge by the IPC exceeds all others, including the proposed refinery, for levels of BOD_5, coliform bacteria, and oils and grease.

g. Sediments

(1) Physical Properties. The sediment types within the Sampit River vary considerably with time and location. This is reflected in sampling results from 1980 and 1981. Figure VI.C-3 presents sampling stations and Table VI.C-8 shows the percentage composition of sand, silt and clay.

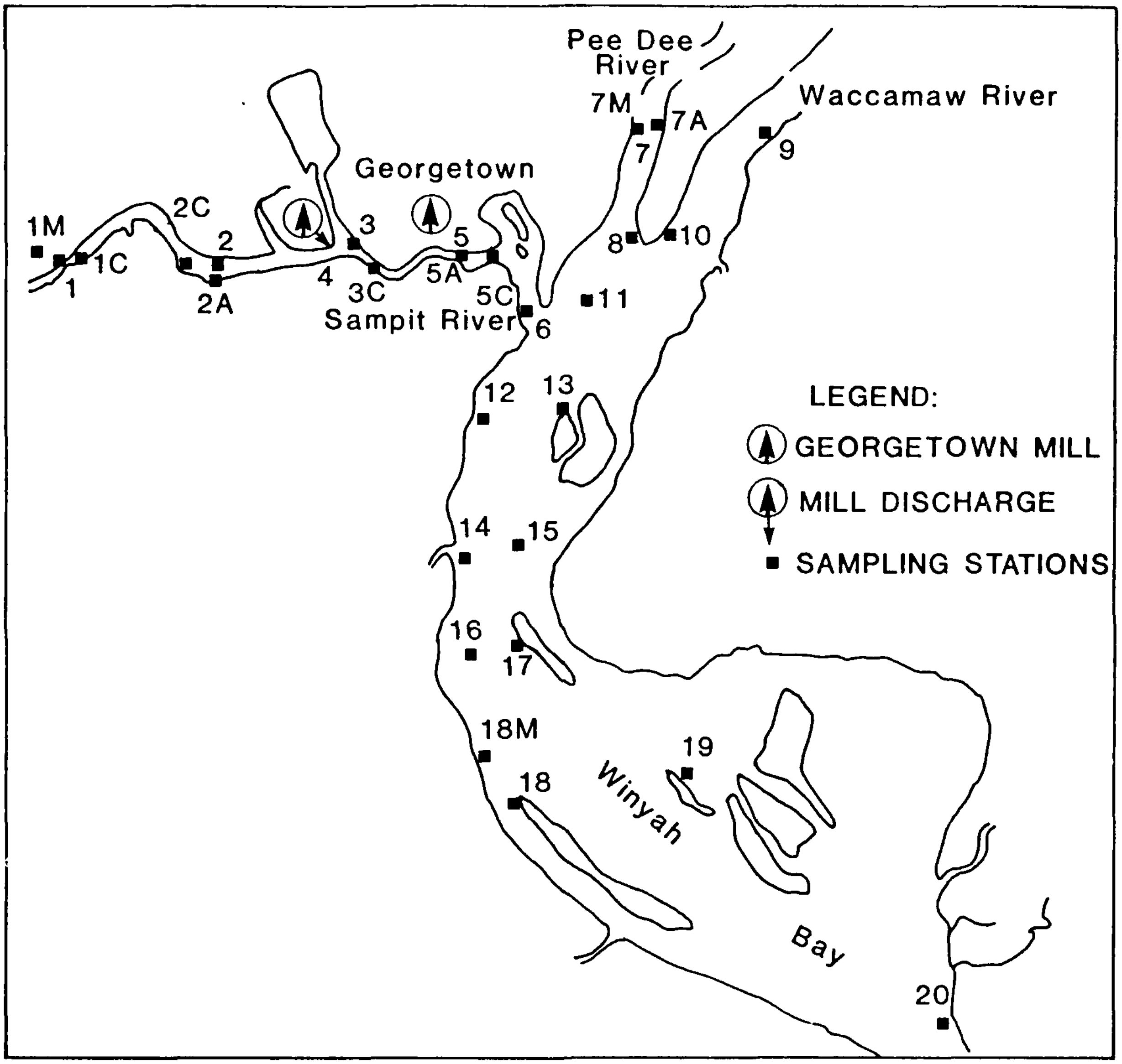


Figure VI.C-3. Sampling stations used for sediment survey conducted in 1980 and 1981.

Source: International Paper Co., 1982.

TABLE VI. C-5

SAMPIT RIVER WATER QUALITY PARAMETERS
BETWEEN PORTS AND PENNYROYAL CREEKS
DHEC NO. MD-075

Parameter	Units	Mean of monthly values[1] 1981	1982	1983
Turbidity	ntu	8.5 (9)	7.5 (11)	9.5 (9)
Conductivity	µmho/cm	10857.0 (7)	8370.0 (6)	11081.0 (8)
Dissolved oxygen	mg/l	6.8 (12)	6.6 (12)	6.3 (11)
BOD_5	mg/l	1.9 (12)	1.4 (12)	1.9 (10)
COD	mg/l	48.5 (2)	40.5 (4)	-
pH		6.8 (11)	6.8 (12)	6.8 (11)
Total Alkalinity	mg/l as $CaCO_3$	48.9 (12)	23.0 (12)	31.4 (10)
Salinity	°/oo	7.2 (7)	4.5 (5)	6.8 (8)
Ammonia	mg/l	0.24 (12)	0.19 (12)	0.14 (7)
Kjeldahl N	mg/l	1.1 (12)	1.0 (12)	0.7 (7)
NO_2/NO_3	mg/l	0.16 (12)	0.14 (12)	0.10 (7)
Phosphorus	mg/l as P	0.11 (12)	0.20 (12)	0.12 (7)
TOC	mg/l as C	14.4 (4)	20.3 (4)	7.7 (2)
Cd	µg/l	<10.0 (4)	<10.0 (4)	<10.0 (2)
Cr	µg/l	<50.0 (4)	<50.0 (4)	<50.0 (2)
Cu	µg/l	<50.0 (4)	<50.0 (4)	<50.0 (2)
Fe	µg/l	900.0 (4)	950.0 (4)	740.0 (2)
Pb	µg/l	213.0 (4)	75.0 (4)	185.0 (2)
Mn	µg/l	87.5 (4)	67.5 (4)	80.0 (2)
Ni	µg/l	120.0 (4)	<50.0 (4)	150.0 (2)
Zn	µg/l	60.0 (4)	60.0 (4)	100.0 (2)
Fecal coliform	col/100ml	46.0 (12)	113.0 (12)	38.0 (10)
Hg	µg/l	0.27 (4)	0.35 (4)	0.35 (2)

[1] Numbers of monthly samples are given in parentheses.

SOURCE: South Carolina Department of Health and Environmental Control, 1984

TABLE VI. C-6

SAMPIT RIVER WATER QUALITY PARAMETERS
NEAR U.S. HIGHWAY 17 BRIDGE
DHEC NO. MD-077

Parameter	Units	Mean of monthly values[1] 1981	1982	1983
Turbidity	ntu	10.2 (9)	9.4 (11)	10.5 (10)
Conductivity	μmho/cm	12000.0 (6)	10850.0 (6)	11015.0 (8)
Dissolved oxygen	mg/l	7.4 (12)	7.1 (12)	6.7 (11)
BOD_5	mg/l	2.2 (12)	1.37 (12)	1.7 (10)
COD	mg/l	47.5 (2)	35.5 (4)	-
pH		6.9 (11)	6.7 (12)	6.9 (10)
Total Alkalinity	mg/l as $CaCo_3$	50.6 (12)	28.0 (12)	28.5 (10)
Salinity	°/oo	8.0 (6)	5.5 (5)	6.6 (8)
Ammonia	mg/l	0.37 (12)	0.14 (12)	0.08 (7)
Kjeldahl N	mg/l	1.63 (12)	0.91 (12)	0.67 (7)
NO_2/NO_3	mg/l	0.18 (12)	0.18 (12)	0.14 (7)
Phosphorus	mg/l as P	0.14 (12)	0.20 (12)	0.10 (7)
TOC	mg/l as C	15.4 (4)	13.6 (4)	5.7 (2)
Cd	μg/l	<10.0 (4)	<10.0 (4)	<10.0 (2)
Cr	μg/l	<50.0 (4)	<50.0 (4)	<50.0 (2)
Cu	μg/l	<50.0 (4)	<50.0 (4)	<50.0 (2)
Fe	μg/l	1000.0 (4)	875.0 (4)	785.0 (2)
Pb	μg/l	152.5 (4)	60.0 (4)	165.0 (2)
Mn	μg/l	87.5 (4)	62.5 (4)	70.0 (2)
Ni	μg/l	85.0 (4)	<50.0 (4)	95.0 (2)
Zn	μg/l	72.5 (4)	<50.0 (4)	<50.0 (2)
Fecal coliform	col/100ml	91.6 (11)	109.4 (12)	50.3 (9)
Hg	μg/l	0.33 (4)	0.35 (4)	0.4 (2)

[1]Numbers of monthly samples are given in parentheses.

SOURCE: South Carolina Department of Health and Environmental Control, 1984

TABLE VI. C-7

REPORTED OR PERMITTED POLLUTANT LEVELS FOR SELECTED INDUSTRIES DISCHARGING TO THE SAMPIT RIVER*

	Carolina Refining and Dist. Co.[1]	International Paper Co.[2]	Georgetown Steel Corp.[3]	City of Georgetown[4]	American Cyanamid Co.[5]	Natural[6]
Receiving stream	Sampit River	Sampit River	Sampit River	Sampit River	Sampit River	
Volume (gpd)	1.095×10^6	24.8×10^6	4×10^5	2×10^6		
(lpd)	4.14×10^6	94×10^6	15.1×10^5	7.57×10^6		
BOD_5 (mg/l)/(kg/day)						
Max.	21.7/90	86/8084	21/31.7	45/340.7		-/1900
Avg.		42/3948	10/15.1	30/227.1		
COD (mg/l)/(kg/day)						
Max.	78.4/325	$600/5.6 \times 10^4$				
Avg.						
TSS (mg/l)						
Max.	38	226	40	45	60	
Avg.		125	22.6	30	30	
pH	6-9	6.7-8.4			6.0-9.0	
Temperature (°C)		Winter/Summer 28/35				
Fecal coliform (colonies/100ml)						
Max.	NA[7]	1400		400		
Avg.	NA	546		200		

TABLE VI. C-7
(continued)
REPORTED OR PERMITTED POLLUTANT LEVELS FOR SELECTED INDUSTRIES
DISCHARGING TO THE SAMPIT RIVER*

	Carolina Refining and Dist. Co.[1]	International Paper Co.[2]	Georgetown Steel Corp.[3]	City of Georgetown[4]	American Cyanamid Co.[5]	Natural[6]
Ammonia (mg/l)/(kg/day)						
Max.	22.4/93	none				
Avg.						
Sulfide (mg/l)/(kg/day)						
Max.	1.2/5	6.1/573.4				
Avg.		3.9/366.6				
Oil and Grease (mg/l)/(kg/day)						
Max.	28.3/117.3	5.3/498	27/40.9			
Avg.		4.6/435	18/27.2			
Phenols (mg/l)/(kg/day)						
Max.	0.2/1	0.01/0.94				
Avg.						
Nitrate/nitrite (mg/l)						
Max.		<1				
Avg.		<1				
Phosphate (mg/l)/(kg/day)						
Max.		3.9/366.6				
Avg.		2.2/206.8				

TABLE VI. C-7
(continued)
REPORTED OR PERMITTED POLLUTANT LEVELS FOR SELECTED INDUSTRIES
DISCHARGING TO THE SAMPIT RIVER*

	Carolina Refining and Dist. Co.[1]	International Paper Co.[2]	Georgetown Steel Corp.[3]	City of Georgetown[4]	American Cyanamid Co.[5]	Natural[6]
Aluminum (mg/l)		7.0			4.0	
Iron (mg/l)		1.25				
Magnesium (mg/l)		3.5				
Manganese (mg/l)		0.7				
Tin (mg/l)		<1				
Titanium (mg/l)		<2				
Antimony (mg/l)		0.018				
Arsenic (mg/l)		0.032				
Beryllium (mg/l)		<0.001				
Cadmium (mg/l)		0.018			0.5	
Chromium (mg/l)	1.7	0.125			0.5	
Copper (mg/l)	0.2	0.025			0.5	
Lead (mg/l)		0.033			0.5	
Mercury (mg/l)	0.06	<0.002				
Nickel (mg/l)		0.102			0.5	
Selenium (mg/l)		0.008				
Silver (mg/l)		0.002				
Thallium (mg/l)		<0.005				
Zinc (mg/l)	1.1	0.124	1500			
Vanadium (mg/l)					500	
Benzene (mg/l)	0.01	0.0028				
Ethylbenzene (mg/l)	<0.01					
Chloroform (mg/l)		0.011				
Methyl chloride (mg/l)		0.030				
Methylene chloride (mg/l)	0.1					
Toluene (mg/l)	0.03	0.0033				
1,1,1-Trichloroethane (mg/l)		0.0018				
2,4-Dichlorophenol (mg/l)		0.0045				
Pentachlorophenol (mg/l)		0.165				
Anthracene (mg/l)	0.001	0.0051				

TABLE VI. C-7
(continued)
REPORTED OR PERMITTED POLLUTANT LEVELS FOR SELECTED INDUSTRIES
DISCHARGING TO THE SAMPIT RIVER*

	Carolina Refining and Dist. Co.[1]	International Paper Co.[2]	Georgetown Steel Corp.[3]	City of Georgetown[4]	American Cyanamid Co.[5]	Natural[6]
Bis (2-ethyl-hexyl) phthalate (mg/l)	2	0.047				
Butyl benzyl phthalate (mg/l)		0.005				
Phenanthrene (mg/l)	0.001	0.006				
Diethyl phthalate (mg/l)	0.03	0.036				
Di-n-butyl phthalate (mg/l)		0.008				
Di-n-octyl phthalate (mg/l)		0.036				
Fluoranthene (mg/l)		0.0032				
Cyanide (mg/l)	0.1	0.8				
1,1,2,2-Tetrachloroethane (mg/l)	<0.01					
Tetrachloroethylene (mg/l)	<0.01					
1,2-Trans-dichloroethylene (mg/l)	<0.01					
Trichloroethylene (mg/l)	<0.01					
2,4-Dimethylphenol (mg/l)	<0.01					
4-Nitrophenol (mg/l)	<0.01					
p-Chloro-m-cresol (mg/l)	<0.01					
Benzo-a-pyrene (mg/l)	0.005					
Chrysene (mg/l)	0.05					
Naphthalene (mg/l)	0.001					
Pyrene (mg/l)	0.01					
PCB 1221 (mg/l)	<0.01					
PCB 1232 (mg/l)	<0.01					
PCB 1248 (mg/l)	<0.01					
PCB 1260 (mg/l)	<0.01					
PCB 1016 (mg/l)	<0.01					

TABLE VI. C-7
(continued)
REPORTED OR PERMITTED POLLUTANT LEVELS FOR SELECTED INDUSTRIES
DISCHARGING TO THE SAMPIT RIVER*

	Carolina Refining and Dist. Co.[1]	International Paper Co.[2]	Georgetown Steel Corp.[3]	City of Georgetown[4]	American Cyanamid Co.[5]	Natural[6]

[1]Typical refinery waste levels with estimated treatment reductions applied (See Section VII.B.2). Maximum daily values unless indicated otherwise. Volume shown is total combined continuous wastewater discharge, used to calculate pollutant concentrations. Mass values for BOD, COD, ammonia and sulfide from process water only. Oil and grease combined mass discharge from process and blowdown waters. TSS from Table VII.B-10.

[2]EPA Permit Request (International Paper Company, 1981). Maximum daily values.

[3]Current NPDES Permit Limitations (scale pit).

[4]Current NPDES Permit Limitations (Max.=Daily Avg./week; Avg.=Daily avg./month).

[5]Current NPDES Permit Limitations. Maximum daily values.

[6]Estimate of BOD_5 from swamps (Lawler, Matuskey and Skelly Engineers, 1977).

[7]Sanitary waste discharged to POTW.

*Data points not entered were either not regulated or not reported.

TABLE VI.C-8

PERCENTAGE COMPOSITION OF SEDIMENT SAMPLES
IN SAMPIT RIVER

	Percentage Composition		
Sample station	Sand[1]	Silt[1]	Clay[1]
May 1980			
3	15.7	28.6	55.7
5A	98.0	0.5	1.5
January 1981			
1	30.4	35.5	34.1
2	25.9	47.4	26.7
2A	25.3	38.2	36.5
3	16.5	23.7	59.8
5	58.0	21.5	20.5
5A	51.5	29.0	19.5
6	10.1	51.5	38.4
July 1981			
1	30.0	47.7	22.3
1C[2]	97.2	1.2	1.6
2	30.0	51.2	18.8
2A	50.0	26.0	24.0
2C[2]	97.8	0.5	1.7
3	96.0	1.3	2.7
3C[2]	98.9	0.3	0.8
4	11.2	35.1	53.7
5	12.1	41.4	46.5
5A	20.2	42.8	37.0
6	6.3	57.8	35.9

SOURCE: International Paper Co., 1982

[1]Wentworth Classification

[2]Samples from deeper channel area

As seen in Table VI.C-8, samples collected in deep channels consist almost entirely of sand-size sediments. In the shallower areas, the sand fractions are significantly less as a result of lower flow velocities. Sediment composition varies noticeably at Station 3. In both May 1980 and January 1981, the samples consisted of approximately 85 percent silts and clays. In the July 1981 sample, the sand fraction was 96 percent. The reverse trend was noticed at station 5A, where the percentage of the sand fraction decreased over time. These variations may reflect dredging, sampling inconsistencies and variations in stream flow.

Sediment analyses for metals are presented in Table VI.C-9. When compared with data in Table VI.C-13, it can be seen that samples at Stations 3 and 5 contained slightly to moderately higher concentrations of copper, mercury, lead and zinc. These data represent a one-time sampling event and, therefore, provide only a generalized characterization of sediments in the river.

(2) Pollutant Assimilation Capacity. Analyses of sediments for trace metals, (Table VI.C-9) show that the sediments are already receiving some pollutants. The principal mechanism by which oil pollution reaches sediments is by the adherence of oil to suspended sediments. If sufficient small particles come together and form flocs, the weight of this agglomerate would increase and sedimentation could occur, depending on flow velocities and water chemistry. Conversely, suspended cohesive matter can remain suspended if the chemical environment does not change. However, when the river meets saline water in the estuary or if waste discharges alter the environment, formation of flocs may occur.

The assimilative capacity of the sediments will be affected by scouring caused by high stream flow, by dredging, which is extensive in the lower Sampit River, and by movement of the freshwater-saltwater interface. Under average flow conditions, sediment-laden river water meets salt water about 1.6 km (one mi) up the Sampit River from the estuary or up to 24 km (15 mi) upstream from the estuary during low river discharge (Davis & Floyd, Inc. and Arthur D. Little, Inc., 1983).

(3) Transport Mechanisms. Riverine sediments are transported in three separate modes: bedload, saltation and suspended load. The bedload component of the sediment flux consists of material that slides or rolls along the bottom of the stream. Saltation may be described as particles of material bouncing along the streambed. The suspended load consists of sediment that is entrained by some critical flow velocity and remains in suspension to be transported for relatively long distances. For practical purposes, transportation by saltation may be dismissed, since this process accounts for a relatively small percentage of the total sediment transported in a stream channel. Normally, saltating sediment is collected in the bedload or suspended load portions of field sampling.

Sediment-transport field sampling has not been conducted in the study area (Colquhoun, personal communication, 1983). Consequently, the conclusions concerning sediment transport are based on experiences in similar coastal areas.

Estimates of the magnitude of sediment loads in the Sampit River can be made by considering the amount of dredge material removed. The Committee on Tidal Hydraulics (1972; as cited in Davis & Floyd, Inc. and Arthur D. Little, Inc., 1983) estimated that .86 million m^3 (1.13 million yd^3) of wet material was dredged annually from the lower Sampit River between 1953 and 1962. This would be reduced to approximately 764,600 m^3 (one million yd^3) after dewatering, for an average of approximately 907,800 metric tons (one million tons) per year. This material is assumed to be terrestrial in origin. It is felt, however, that this does not represent the actual bedload and suspended sediment load of the Sampit River, since

TABLE VI.C-9

SEDIMENT ANALYSIS FOR METALS AT
SELECTED STATIONS IN THE SAMPIT RIVER
1981*

	Station			
Chemical analysis	1	3	5	6
Solids %	24.6	32.1	30.6	39.4
Arsenic	28	62	21	68
Copper	6.6	10	11	11
Cadmium	0.20	0.20	0.20	0.20
Chromium	2.8	5.1	5.6	8.9
Cobalt	7.7	6.2	5.3	8.7
Mercury	<0.20	0.93	0.45	<0.20
Nickel	4.3	3.9	3.9	4.7
Lead	21	22	23	22
Zinc	26	36	44	26

SOURCE: International Paper Co., 1982

*Arsenic and mercury concentrations expressed in μg/g of sediment dried at 60°C. Remaining metal concentrations expressed as μg/g dried at 100°C.

the maintenance dredging of the lower Sampit River results in the introduction of sediments from upper Winyah Bay, as will be discussed in Section VI. C.4.g.3.

4. Winyah Bay

Winyah Bay (see Figures VI.C-1 and VI.C-2) is one of the largest estuaries along the southeast coast of the United States. It encompasses approximately 49 km^2 (19 mi^2; May, 1982) from the upper influxes of the Pee Dee, Waccamaw, Black and Sampit Rivers to its outlet into the Atlantic Ocean. It is characterized by an extensive marsh and wetlands system along its shoreline. It is a tidal estuary classified as partially mixed, having two-layer flow with some vertical mixing due to river flow and tidal currents (Matthews et al., 1980).

Other physical characteristics include a total length of about about 21 km (13 mi) from Georgetown to the ocean with widths varying from 1.6 to 6.4 km (one to four mi). The depth of Winyah Bay varies considerably with location and tide, from very shallow mud flats to deeper, natural channel depths of 7.6 km (25 ft) or more in the lower part of the Bay (Henningson, Durham and Richardson, 1976).

A 8.2-meter (27-foot) deep dredged channel has been maintained through Winyah Bay from the mouth between North and South Islands to Georgetown Harbor. This channel is maintained primarily to allow industrial shipping traffic to traverse to the Port Authority docks in Georgetown Harbor. Additionally, the upper reaches of Winyah Bay, from near Estherville Plantation to the mouth of the Waccamaw River, serve as part of the Intracoastal Waterway. This section of the bay is dredged as the "western" channel and joins the "eastern" shipping channel in the vicinity of Belle Isle Gardens. The combined channels proceed north to the entrance to Georgetown Harbor. The Intracoastal Waterway then continues on up the Waccamaw River.

The northeastern portion of Winyah Bay includes areas surrounding ecologically sensitive shorelines in a section called Mud Bay and connects with various tributaries to an even more sensitive ecological area, the North Inlet area.

Overall water quality in Winyah Bay was assessed as only "fair" for water years 1979 through 1981 and trends indicated water quality may have been declining (Knox and Turner, 1982). Assessment for 1982 and 1983 has not been made, but current water quality data, which will be discussed in Section VI. C.4.e., indicated a possible improvement trend. The major sources of pollution are industrial discharges from Georgetown Harbor and the Sampit River and agriculturally-related nutrient pollution from the Pee Dee and Waccamaw River inflow.

a. Existing Water Uses. Winyah Bay is used to transport industrial shipments from the Atlantic Ocean coastal shipping lanes to the entrance of Georgetown Harbor and to ship refined or manufactured goods from Georgetown to other areas. The Intracoastal Waterway section of Winyah Bay is used as a transportation route by barges carrying materials and goods from Charleston, South Carolina, as well as other places to the south, to Georgetown and further north. Numerous barge shipments of fuel oil pass through this stretch of the bay destined for Myrtle Beach Air Force Base (Doyle, personal communication, 1983). In addition to industrial traffic, Winyah Bay and the Intracoastal Waterway are utilized by smaller commercial and recreational craft. Portions of Winyah Bay, particularly the northeastern areas near North Inlet, are used for research studies on estuarine habitats and characteristics. The use of Winyah Bay waters and surrounding areas by a number of endangered and protected species will be detailed elsewhere in this report.

Winyah Bay waters are classified SC under the Water Classification Standards System for the state of South Carolina. This classification is the same as that applied to the lower reaches of the Sampit River, discussed previously, and is the lowest classification that can generally be assigned. Class SC waters are tidal salt waters suitable for secondary-contact recreation, the survival and propagation of marine flora and fauna, and fishing or crabbing but no commercial harvesting of clams, mussels or oysters (DHEC, 1983). Quality standards are as outlined previously in Table VI.C-3.

b. Winyah Bay Flow Characteristics. Determination of current flow direction and other aspects of water motion in Winyah Bay are critical in evaluating the extent of impacts from oil spills or chronic discharge of waste into the bay. However, for a given time and location, this determination is very complex and related to a number of factors. An acceptable calibrated mathematical model for Winyah Bay hydraulic properties is not yet available. As for most estuarine systems, a Winyah Bay model would have to take into account the complex effects of salinity-density variations, freshwater mass flow, winds, topogaphical features of the basin, and tidal amplitude variations on dispersion and flushing characteristics. Freshwater inflow from the Black, Pee Dee and Waccamaw Rivers varies seasonally as do wind direction and force. Tides are semidiurnal, flooding and ebbing in roughly 12.5-hour cycles, and varying in magnitude throughout the 28-day lunar cycle (May, 1982). The following discussion pertains to general flow characteristics in Winyah Bay and those factors that influence this flow.

Freshwater inflow into Winyah Bay causes a net mass flow of water down through the bay and out into the Atlantic Ocean. This inflow is mainly a combination of freshwater flow from the Pee Dee, Waccamaw and Sampit Rivers. Pee Dee River inflow is estimated by combining reported flows as four USGS guaging stations: Pee Dee River at Pee Dee, SC; Lynches River at Effingham, SC; Little Pee Dee River at Galivants Ferry, SC; and Black River at Kingstree, SC. Monthly measurements of Waccamaw River flow into Winyah Bay have not been made. However, the Waccamaw River contributes only about 10 percent of the total flow into Winyah Bay (May, 1982). The Sampit River, as discussed previously, has negligible freshwater input. Therefore, values of freshwater inflow into Winyah Bay are estimated by combining the average annual flowrate for the Waccamaw River with estimates of Pee Dee River inflow based on measurements at the four USGS guaging stations. Table VI.C-10 shows seasonal variations in freshwater flow into Winyah Bay.

Tides in Winyah Bay average about 1.2 m (4 ft) at the mouth of the bay and 1.0 m (3.3 ft) in Georgetown Harbor. These tidal ranges may increase to 1.4 m and 1.2 m (4.7 ft and 3.9 ft) for the mouth and harbor, respectively, during spring tides (NOAA, 1983). During flooding, shallow currents may be directed up into the bay. Deeper channel currents will be affected not only by the tidal rise but flow up the bay may be assisted by density gradients caused by the higher salinity waters. These density currents, combined with flood currents, can transport silt loading up into the Sampit River, causing flocculation, sedimentation and possible pollutant entrapment (Henningson, Durham and Richardson, 1976). Ebb tides will reverse the direction of most surface currents and an increase in net velocity may occur with the addition of the river current component. For those currents in deeper channels, density currents may still create a net upstream movement during ebb tide. Local current direction and velocities will be affected by bottom topography for the deeper currents and wind effects and local topography for the shallower surface currents.

TABLE VI.C-10

ESTIMATED SEASONAL FRESHWATER INFLOW
TO WINYAH BAY

Season	Pee Dee River Flowrate[1]	Waccamaw River Flowrate[2]	Total Inflow
	m^3/sec (cfs)	m^3/sec (cfs)	m^3/sec (cfs)
Winter (Jan-Feb-Mar)	800 (28250)	34 (1200)	834 (29450)
Spring (Apr-May-Jun)	530 (18730)	34 (1200)	564 (19930)
Summer (Jul-Aug-Sep)	306 (10790)	34 (1200)	340 (11990)
Fall (Oct-Nov-Dec)	305 (10775)	34 (1200)	339 (11975)
Annual	480 (16950)	34 (1200)	514 (18150)

[1] Seasonal values represent 10-year average of 3 month averaged flows at USGS guaging stations. Annual value represents 10-year average of USGS reported calendar year average. (USGS, 1984)

[2] Annual average (Matthews et al., 1980)

North Inlet is a relatively small, high salinity estuary where research is currently in progress (Figures VI.C-1 and VI.C-2). Flow between Winyah Bay and North Inlet is of much concern for an evaluation of impacts from possible oil spills or other pollution in Winyah Bay. Some studies have been conducted (Schwing and Kjerfve, 1980; Allen et al., 1982) that characterize flow between Winyah Bay and North Inlet. Schwing and Kjerfve reported that about 80 percent of channel flow between North Inlet and Winyah Bay occurs through Jones Creek. A nodal point exists in the channel that serves to protect North Inlet somewhat from a regular intrusion of Winyah Bay waters through Jones Creek. During the tidal cycle, waters from Winyah Bay and North Inlet flow to and meet at this nodal point on flooding and flow away to respective main bodies on ebbing. However exchange of Winyah Bay waters with North Inlet occurs regularly from sheet flow over a 34 km^2 salt marsh that separates the two estuaries. In addition, the nodal point in Jones Creek can be overridden during times of high freshwater discharge from the Pee Dee River, especially when combined with excessive rain and wind stress (Kjerfve, personal communication, 1983).

Studies of No Man's Friend Creek and South Jones Creek were conducted to determine flow patterns during the tidal cycle (Allen et al., 1982). At No Man's Friend Creek it was found that ebb tides initially produced currents toward Winyah Bay for two to five hours but, during the next two to four hours, the current was directed toward North Inlet. Studies of flood tides revealed that, on almost two-thirds of the tides, the flood current direction was toward North Inlet. However, a little over one-third of the tides studied showed flow current heading toward Winyah Bay. They reported that the direction of the flood tides appeared to be related to the tidal amplitude. Tides less than 1.75 m (5.74 ft; low) would produce flood currents directed toward Winyah Bay, while tidal amplitude greater than 1.75 (5.74 ft; high) would cause the current to flow toward North Inlet.

Similar studies conducted or South Jones Creek (Allen et al., 1982) revealed that of the tidal cycles studied, all ebb tides produced currents in the direction of Winyah Bay and all flood tides produced currents in the direction of North Inlet. The existence of a nodal point was also discerned.

c. Flushing Characteristics. Detailed studies of the flushing characteristics of Winyah Bay are not available. The tidal, density, river-inflow and wind-induced currents within an estuary such as Winyah Bay will combine to form a complex system of fluid motion. Flushing of pollutants from the bay will most likely vary considerably with the location of the pollutant source within the bay. Flushing of the silt loading brought into the bay by river inflow has been found to be minimal, mostly due to sedimentation of this silt in the vicinity of the saline-freshwater interface. Therefore, any pollutants adsorbed by this silt will likely be retained within the bay for some time. Flushing of dissolved or emulsified pollutants, which remain in the water column, may be more complete.

d. Salinity Profile. The salinity profile for Winyah Bay varies with tidal cycle, tidal amplitude, and freshwater inflow from the Pee Dee and Waccamaw Rivers. Surface and bottom salinity measurements in the bay show some stratification, with denser, more saline waters near the bottom and fresher waters near the surface. However, the difference is not great, varying no more than 10 parts per thousand during one sampling period (Allen et al., 1982). The upper levels of the bay near the freshwater influx also exhibit a variance

between surface and bottom salinities, but overall values are less than those for the lower portions of the bay.

Salinity values are important in characterizing the chemical constituency of the bay waters. The location of the freshwater-saltwater interface is important for evaluating the probable location of maximum flocculation and sedimentation of suspended silt, which may carry with it adsorbed pollutants. A study of salinity profiles in Winyah Bay (Johnson, 1970) produced data that can be used to generally determine the location of the freshwater-saltwater interface for various levels of freshwater inflow. Figure VI.C-4 is a useful presentation of this information and is based upon measurements for high-slack tide. The freshwater boundary was assumed to be at a specific conductance of 800 micromhos per centimeter.

The characteristics of the tide, river inflow and the physical dimensions of the bay will influence the location of the freshwater-saltwater interface during the tidal cycle. The interface will move up the bay on flood tide and recede on ebb. The actual movement will be affected by the inertia of the water mass, and, therefore, maximum intrusion may not occur until high-slack tide, and the minimum at ebb-slack tide. At high-slack tide, the interface may reach up to 3.2 km (two mi) on the Black River and eight km (five mi) on both the Pee Dee and Waccamaw during average freshwater inflow (510 m^3/sec or 18,000 cfs). If the freshwater inflow is low, the interface may reach as far as 25.7 km (16 mi) on the Pee Dee and Waccamaw Rivers and 21 km (13 mi) on the Black River. High freshwater inflow of 990 m^3/sec (35,000 cfs) or more may hold the interface to near the mouth of the rivers (Johnson, 1970).

e. Water Quality. Winyah Bay water quality received an overall assessment of "fair" by the South Carolina Department of Health and Environmental Control for water years 1979 through 1981. Winyah Bay was rated as "good" for temperature, pH, oxygen, bacteria, aesthetics, solids and inorganic toxicity, and "fair" for trophic/nutrients (Knox and Turner, 1982). An explanation of these ratings was presented in Section VI. C.3.e. Current water quality data are only available for one sampling station in the upper portion of Winyah Bay near the confluence of the Pee Dee and Waccamaw Rivers. Table VI.C-11 shows the annual average concentrations for various components measured at this station. Evaluation of these data indicates some reduction in the concentration of nutrients during the three-year period represented.

Dissolved oxygen and the level of nutrients and metals will vary with location in the bay, season of sampling, discharge conditions of pollutant sources and river inflow. Dissolved oxygen values are generally lower in the summer months and in areas near known pollutant discharges (Moore, Gardener and Associates, Inc., nd.). Total nitrogen and phosphorus levels measured near No Man's Friend and South Jones Creeks show peaks in the summer corresponding to periods of high biological productivity (Allen et al., 1982).

Baseline petroleum hydrocarbon measurements of samples taken from the top 20 cm of the water column between October 1981 and November 1982 (Bidleman and Svastits, 1983) show that the waters of Winyah Bay were relatively clean with respect to petroleum hydrocarbons. Levels measured were more typical of continental shelf waters than industrialized estuaries. Total hydrocarbons, measured by gas chromatography from samples collected just north of Rabbit Island were 1.7 μg/l or less. Measurements made in Mud Bay revealed levels less

than 1.0 μg/l. Bidleman and Svastits (1983), however, point out that hydrocarbon concentrations in the water column are transient due to removal by sedimentation and suggest that further study of pollutants in Winyah Bay should include a survey of the sediments for hydrocarbons. Olsen et al. (1982, as cited in Michener and Allen, 1984), in a study of low, sustained concentrations of petroleum hydrocarbons in temperate estuaries, concluded that "...oil disappeared rapidly from the water column...' and "Approximately half the oil added to the water column became incorporated in surface sediments, and here it persisted and had severe, long-lasting effects on the longer-lived benthos."

f. Existing Pollutant Sources. The Sampit River and Georgetown Harbor are the source of most of the industrially-related pollutants in Winyah Bay including most of the metals, petroleum hydrocarbons, and oxygen-demanding pollutants. A more detailed listing of these sources was included in the discussion on the Sampit River. Much of the nutrient loading is believed to be non-point source, related to agricultural runoff and discharged into the bay by the Pee Dee and Waccamaw Rivers and, to some extent, along the shoreline of the bay. The Waccamaw River is believed to be the primary source for total phosphate levels in the bay (Henningson, Durham and Richardson, 1976).

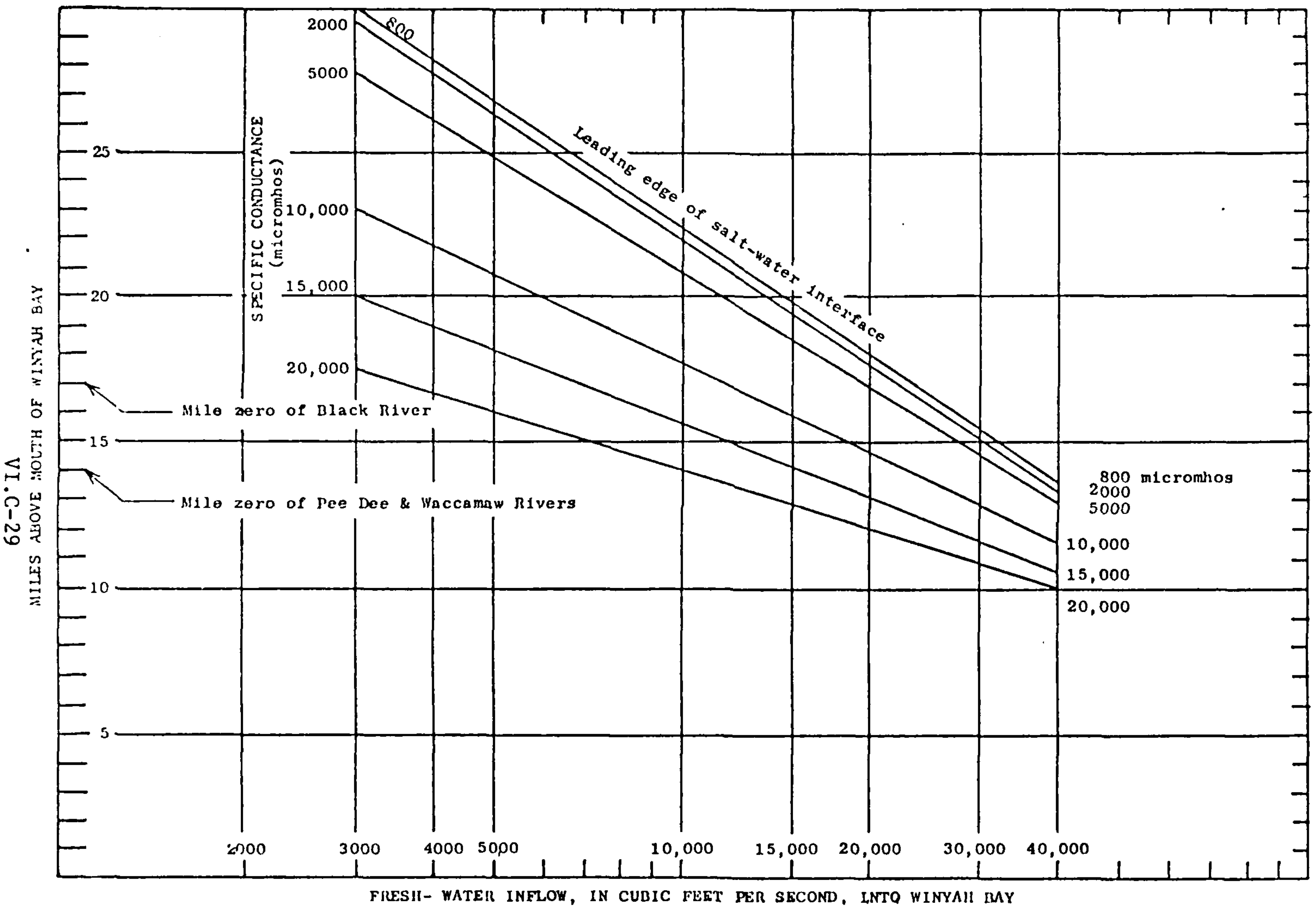


Figure VI.C-4. Bottom-specific conductance values at high-slack tide in Winyah Bay estuarine zone. (Johnson, 1970)

TABLE VI.C-11

WATER QUALITY PARAMETERS FOR WINYAH BAY WEST OF MARKER 92
(Near confluence of Pee Dee and Waccamaw Rivers)
DHEC NO. MD-080

Parameter	Units	Mean of monthly values[1] 1981	1982	1983
Turbidity	(NTU)	9.0 (9)	7.3 (11)	12.6 (10)
Conductivity	(μmho/cm)	10500 (7)	8030 (7)	8943 (8)
DO	(mg/l)	7.8 (12)	7.8 (12)	7.4 (11)
BOD_5	(mg/l)	2.7 (12)	1.5 (12)	1.9 (10)
COD	(mg/l)	22.0 (8)	24.7 (8)	29.4 (5)
pH		7.1 (11)	6.8 (12)	6.9 (11)
Total Alk.	(mg/l as $CaCO_3$)	38.6 (12)	24.2 (12)	27.7 (10)
Salinity	o/oo	7.0 (6)	5.2 (6)	4.8 (8)
Ammonia	(mg/l)	0.35 (12)	0.38 (11)	0.09 (6)
Kjeldahl N	(mg/l)	1.4 (12)	1.22 (12)	0.69 (8)
NO_2/NO_3	(mg/l)	0.20 (12)	0.22 (12)	0.18 (6)
Phosphorus	(mg/l as P)	0.14 (12)	0.20 (12)	0.08 (6)
TOC	(mg/l as C)	10.6 (7)	16.6 (6)	6.6 (2)
Cd	(μg/l)	<10.0 (4)	<10.0 (4)	<10.0 (2)
Cr	(μg/l)	<50.0 (4)	<50.0 (4)	<50.0 (2)
Cu	(μg/l)	<50.0 (4)	<50.0 (4)	<50.0 (2)
Fe	(μg/l)	1350 (4)	1000 (4)	670 (2)
Pb	(μg/l)	130.0 (4)	57.5 (4)	180.0 (2)
Mn	(μg/l)	77.5 (4)	55.0 (4)	60.0 (2)
Ni	(μg/l)	120.0 (4)	<50 (4)	110.0 (2)
Zn	(μg/l)	137.5 (4)	225 (4)	110.0 (2)
Fecal col.	(col/100ml)	45.3 (12)	50.6 (12)	33.0 (8)
Hg	(μg/l)	0.3 (3)	0.4 (4)	0.5 (2)

[1]Numbers of monthly samples are given in parentheses.

SOURCE: South Carolina Department of Health and Environmental Control, 1984

Sources for petroleum hydrocarbon pollution, mainly attributed to discharges from the IPC and Georgetown Steel Corporation, may also be atmospheric deposition and losses from ship, barge and pleasure craft on the bay and bay sections of the Intracoastal Waterway.

g. Sediments

(1) Physical Properties. Sediment sampling data are presented for the years 1971, 1980 and 1981. The sample data are shown in Table VI.C-12 and locations in Figure VI.C-5. Variations between the data for January and July 1981 are most noticeable at Stations 13, 14, 15 and 18. Furthermore, when comparing 1971 and 1981 data, it can be seen that Stations 12, 13, 14, 15 and 18 have markedly differing values. The 1971 results, seen in Figure VI.C-5, are based on over 200 grab samples. This indicates that the bottom environment is in a constant state of change as a result of factors such as stream flows, currents, storm events, dredging and tidal fluctuations. Generally, the coarser material is to be found below the mouths of the Pee Dee and Waccamaw Rivers at the mouth of bay, and in mid-bay, where the Intracoastal Waterway is located.

Unfortunately, the extent of the data is limited and the bottom variations are unknown for even a single calendar year. Nevertheless, a generalized picture is available. The limited results show that shallower areas, especially Mud Bay, have lower sand fractions as a result of lower flow velocities. Given the large size of the drainage area 106,112 km^2 (40,970 mi^2), it is not surprising that bottom conditions would change with time.

Sediment analyses for metals are presented in Table VI.C-13. These include replicate and duplicate samples. Replicates are samples that were submitted and analzyed as two distinct samples from the same location. Duplicates were produced after the original wet sample was dried and homogenized and two different 5-gram portions were digested. Results from duplicate samples showed excellent analytical agreement, but results from replicates were not as good. Even so, the results represent only a one-time sampling event and provide only a generalized characterization of sediments at the time of collection.

(2) Pollutant Assimilation Capacity. Winyah Bay is a complex estuarine system that is influenced by variations in river flows, precipitation, wind direction and velocity, tidal fluctuations, currents and eddys. These factors have significant impacts on bottom environments, shoals, channels, sandbars, stream banks, islands and inlets. As a consequence, two identical pollution events could develop into vastly differing scenarios.

With respect to oil pollution, the distribution and persistence of spilled oil in sediments are controlled primarily by the hydrographic energy (wave conditions and tidal-current velocities) and sediment type of the environment impacted by the oil. According to Gundlach et al. (1978), oil is readily buried or penetrates into coarse-grained sediments, where it may remain in a relatively unmodified state for years. Fine-sand beaches are the least vulnerable to long term impacts from spills because of low penetration rates into the sand on such beaches. Sheltered tidal flats and salt marshes, such as Mud Bay and vicinity, can retain oil in sediments for years.

Mechanisms resulting in sinking of oil include the adherence of oil to suspended sediments, which eventually sink to the bottom, and adherence of oil to intertidal sediments with associated transport of the oiled sediment offshore by bottom currents. The roles of dispersants, flocculation and water turbulence in sinking of oil are, as yet, unclear (Gundlach et al., 1978).

TABLE VI.C-12

PERCENTAGE COMPOSITION OF SEDIMENT SAMPLES IN WINYAH BAY[1,4]

Sample station	Sand[1,2] (%)	Silt[1,2] (%)	Clay[1,2] (%)	Sand[2,4] (%)
		May 1980		1971
14C[3]	4.1	58.4	37.5	0-25
		January 1981		
12	88.3	5.8	5.9	0-25
13	16.5	58.3	25.2	25-50
14	8.8	68.2	23.0	0-25
15	56.3	34.8	8.9	0-25
18	34.3	44.8	20.9	0-25
19	14.6	56.8	28.6	0-25
		July 1981		
12	94.7	1.8	3.4	0-25
13	64.6	30.9	4.5	25-50
14	81.8	13.1	5.1	0-25
15	7.4	69.4	23.2	0-25
18	16.3	69.9	13.9	0-25
19	14.5	48.2	37.3	0-25

SOURCE: International Paper Co., 1982.

[1]Impact of the Georgetown Mill on the Sampit River and Winyah Bay, South Carolina, Volume 2.

[2]Wentworth Classification.

[3]Sample from deeper channel area.

[4]Colquhoun, D.J. 1973. For comparative purposes it is presented next to data collected in 1980 and 1981.

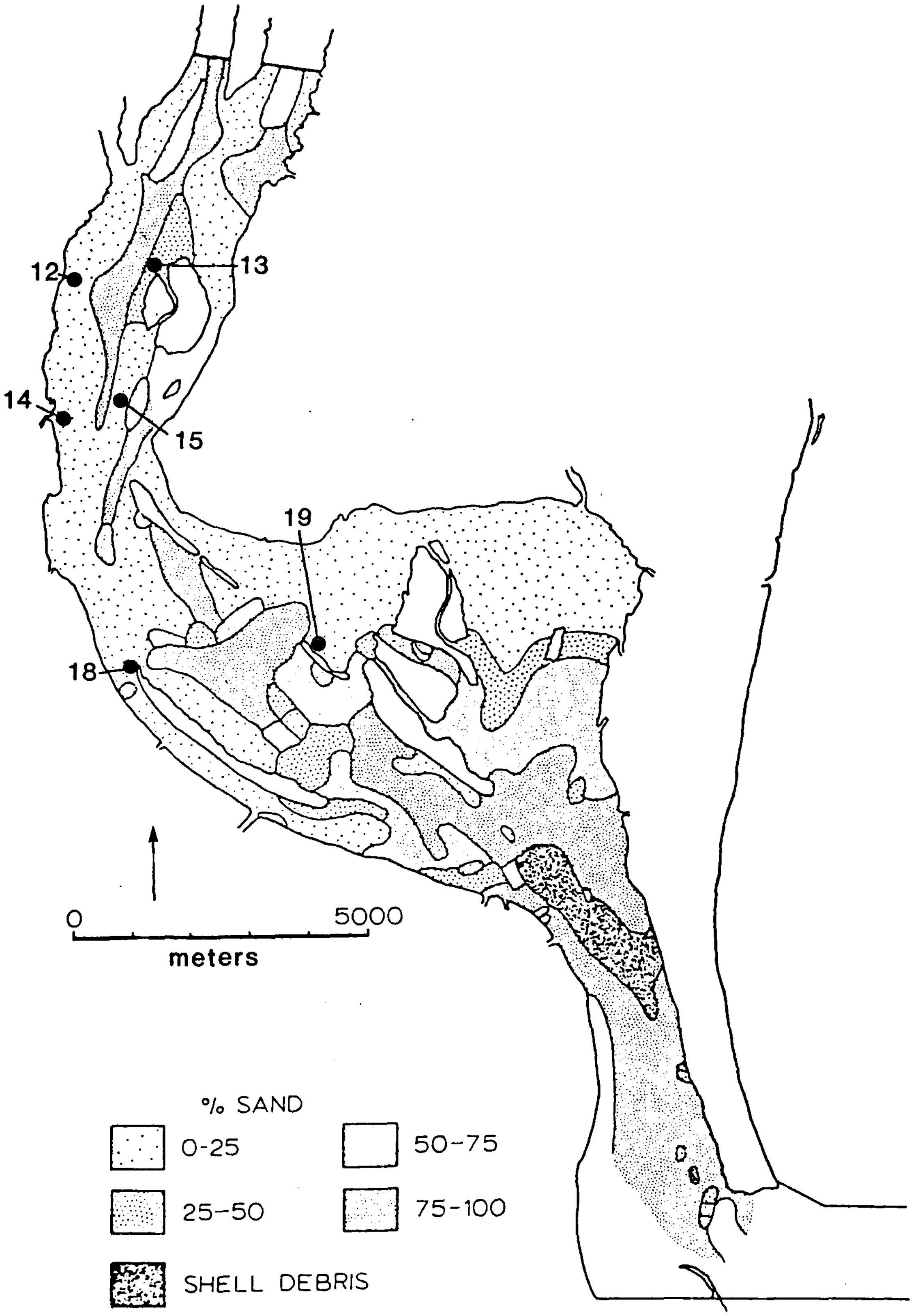


Figure VI.C-5. Identification of Deposited Sediments[1] and Locations of Sediment Sampling Stations[2] in Winyah Bay, South Carolina.

[1]Colquhoun, D.J., 1973.
[2]International Paper Co., 1982.

TABLE VI.C-13

SEDIMENT ANALYSIS FOR METALS AT
SELECTED STATIONS IN WINYAH BAY
1981[1]

	Station					
Chemical analysis[4]	12[2]	13[2]	13[2]	15	15[3]	19
Solids %	63.5	34.1	-	41.5	42.9	42.5
Arsenic	7	58	-	33	-	34
Copper	3.0	10.0	10.0	6.7	6.4	6.8
Cadmium	<0.20	0.34	0.20	<0.20	<0.20	<0.20
Chromium	5.4	11.0	11.0	7.9	7.6	8.0
Cobalt	2.4	9.5	9.6	5.5	4.8	5.8
Mercury	0.20	<0.20	-	<0.20	-	1.0
Nickel	1.4	4.9	4.3	2.9	2.6	3.9
Lead	6.4	19.0	19.0	13.0	14.0	15.0
Zinc	12	21	20	20	19	19

SOURCE: International Paper Co., 1982

[1]Arsenic and mercury concentrations expressed in μg/g of sediment dried at 60°C. Remaining metal concentrations expressed as μg/g dried at 100°C.

[2]Analyzed as blind duplicates. Extracts prepared from dried, homogenized soil.

[3]Analyzed as replicate. Original wet sample submitted in separate container.

It is recognized that oil incorporated with sediments does not undergo the same processes as oil exposed to the atmosphere or present within the water column, since the absence of oxygen and shielding from sunlight would retard microbial degradation.

A significant percentage of water soluble, heavier-than-water, and dispersed-droplet petroleum fractions could accumulate in the sediments. The heavier fraction would simply settle to the bottom because of greater density, while the soluble and droplet fractions could adhere to the suspended materials, silts and clays present in the bay. Subsequently, some percentage of the suspended particles could be expected to settle out of the water column. Once contained in the bottom sediments, the oil may persist for long periods under the anaerobic or near-anaerobic conditions that predominate in some surface and most subsurface sediments in the bay. It should also be recognized that contaminants deposited at one location can be spread to other areas by the movement of sediments in the bay system. This could include movement through the inlet during certain times.

Due to the variable nature of pollutant inputs, either chronic or single-episode accidents, accumulation into the sediments would not be uniform with time or location. For example, greater accumulations in the sediment could be expected in the vicinity of Pier 31 (SC State Ports Authority), where there would be continuous handling of both raw crude oil and refined products. Likewise, the Mud Bay region, a sediment sink area, appears to be more vulnerable to pollutant accumulation.

Ultimately, however, several key issues defined by Gundlach et al. (1978) require further study. In summary, they are as follows:

- How does oil interact with suspended sediments and organic matter?
- What are the effects of contamination of interstitial water?
- What are the interactions between trace metals in oil and sediments?
- What are the precise mechanisms behind the sinking of oil?
- Where does the oil go (i.e., determining an oil spill mass budget)?

There are partial answers to the above questions; these are incorporated into Section VII.B of the report.

(3) Transport Mechanisms. Terrestrial sediments in Winyah Bay originate in four physiographic provinces through which the bay's major rivers and tributaries traverse. Each of the physiographic provinces has characteristic soil types, slopes, vegetative cover and varying erosion rates. Sediment is eroded at the fastest rates and transported in the largest concentrations in the steep-slope drainage basins in the Piedmont Province. In transit to the bay, artificially impounded lakes, natural swamps, freshwater wetlands and ponds trap much of the sediment flowing into the Yadkin and Pee Dee drainage basin. Most of the sediment is transported to Winyah Bay by the relatively flat rivers that drain a large area in the Southern Coastal Plain (Conservation Foundation, 1980, as cited in Davis and Floyd, Inc. and Arthur D. Little, Inc., 1983). The respective sediment contributions are as follows: Atlantic Coast Flatwoods, 26 percent; southern Coastal Plain, 45 percent; Sandhills, 11 percent; and Piedmont; nine percent. Nearly all of the sediment is in the form of silt and clay by the time it reaches Winyah Bay. Figure VI.C-5 shows the distribution of sediments in the bay, including the relative extent of marine sands near the entrance channel on the ocean and the predominating silts and clays in the upper portion of the bay.

The Soil Conservation Service (1979) has estimated that the rivers transport 1.14 million m^3 (1.5 million yd^3) of sediment per year. They further calculated that the sum of sediment entering Winyah Bay is closer to 0.76 million m^3 (one million yd^3) per year, allowing for deposition of sediments on river banks during periods of overbank flow. By contrast, the Army Corps of Engineers calculated the sediment load of the Pee Dee River and its tributaries to be about 2.6 million m^3 (3.4 million yd^3) per year (Committee on Tidal Hydraulics, 1972 as cited in Davis & Floyd and Arthur D. Little, Inc., 1983).

The Committee on Tidal Hydraulics recommends gross sediment volume estimates of 1.2 million m^3 (1.6 million yd^3) as the best estimate of material dredged within Winyah Bay and the Sampit River from 1953 to 1962. Using the dredging proportions in the bay given by the Army Corps of Engineers, the total dredging for each depositional environment becomes:

Lower Sampit River	71%	.86 million m^3 (1.13 million yd^3)
Winyah Bay	19%	.23 million m^3 (.31 million yd^3)
Entrance Channel	10%	.12 million m^3 (.16 million yd^3)

The fact that the Soil Conservation Service estimate of .76 million cubic m^3 (one million yd^3) sediment yield is less than the volume of silt and clay dredged from the lower Sampit River can be partially accounted for by correcting for the weight of water in the dredged-volume calculations. The 2.6 million m^3 (3.4 million yd^3) of sediment yield measurement was justified by the Army Corps of Engineers by assuming that the difference was caused by sediment flushing out of the estuary. There is evidence of some sediment flushing during peak discharge. However, if sediment was being flushed continuously, there would be more evidence of it, such as more silt deposited toward the outlet of the estuary. The Army Corps' sediment yield measurements were also taken when the freshwater inflow was at peak discharge of about 906 m^3/sec (32,000 cfs), but the sediment yield calculations were made using average annual discharge estimates of 453 m^3/sec (16,000 cfs) (Committee on Tidal Hydraulics, 1972 and U.S. Army Corps of Engineers, 1978, as cited in Davis & Floyd, Inc. and Arthur D. Little, Inc., 1983).

5. Coastal Areas

Coastal areas near Winyah Bay and adjacent sections of the Atlantic Ocean are the primary recipients of pollutants flushed from Winyah Bay. Most pollutants are diluted rapidly to negligible concentrations upon discharge to the Atlantic Ocean. A major exception, for example, would be a large oil spill from a tanker preparing to transit the Winyah Bay entrance.

Nearshore currents in the vicinity of Winyah Bay are relatively unknown; however, available data indicate that these nearshore currents vary seasonally and somewhat with meterological conditions, such as major storms. Nearshore current directions appear to be complicated by movement of the Gulf Stream onto the Continental Shelf in winter and offshore during other times of the year. A zone of year-round upwelling has been identified east of Charleston and south of Georgetown, and cyclonic eddies from the Gulf Stream appear to be in place during the spring and summer (Mathews and Pashuk, 1977 and 1982).

In winter, weak, wind-driven currents move generally northward along the coast off Winyah Bay. Stronger southward or southwestward currents begin developing in late March and reach greatest intensity between May and September; the currents then diminish in strength and begin to move northerly again by late November (Mathews and Pashuk, 1977 and 1982; Stender, personal communication, 1984).

D. FISH AND WILDLIFE RESOURCES OF THE WINYAH BAY AREA

1. WILDLIFE RESOURCES

The diversity of habitat types as well as the large areas of undeveloped landholdings extant in the bay area provide important refuge for a rich variety of wildlife species.

a. Birds

The Winyah Bay system is a part of one of the most important overwintering refuge areas for migratory waterfowl in the Atlantic Flyway. In and adjacent to the bay are over 80,000 acres of protected waterfowl refuge habitats under State and Federal management. Considered together as a resource unit, the Yawkey Wildlife Center, Samworth Management Area, Santee Coastal Reserve, and Cape Romain National Wildlife Refuge provide refuge for peak waterfowl concentrations of over 85,000 to 105,000 birds. The most important feeding and resting habitats for migratory waterfowl in Winyah Bay are the estuarine impoundments described elsewhere in this report. Significant numbers of diving ducks also utilize estuarine open water areas of the bay for feeding and resting habitat. According to data from the U.S. Fish and Wildlife Service midwinter waterfowl survey up to 6,000 waterfowl have been recorded in the open water areas of the bay during aerial counts. A significant roosting area regularly harboring 4-6,000 mallards is present in the open marsh between Cat Island and South Island (Bob Joyner, S.C. Wildlife and Marine Resources Department, personal communication). It is likely that significant waterfowl movement occurs regularly between open water areas and estuarine impoundments, depending on weather or local disturbances.

Dabbling ducks that are common in fresh to brackish wetlands include the mallard, black duck, gadwall, blue-winged teal, green-winged teal, pintail, wood duck, American widgeon and northern shoveler.

Diving ducks, including lesser scaup, greater scaup, canvasback, redhead, red-breasted merganser, hooded merganser, ruddy duck, bufflehead, and common goldeneye, utilize the more saline marshes and open water areas. Canada geese also winter in the bay area.

Other important game birds in the bay area include wild turkey, bobwhite quail, mourning dove, American woodcock, common snipe, Virginia rail, clapper rail, king rail, sora, common gallinule and American coot.

Shore and wading birds are common in the bay area with characteristic assemblages present in palustrine, estuarine, and coastal marine wetland habitats. Common wading birds include the great blue heron, little blue heron, green heron, Louisiana heron, snowy egret, great egret, and black-crowned night heron. Shorebirds include the American oystercatcher, black-bellied plover, semipalmated plover, spotted sandpiper, willet, greater yellowlegs, and ruddy turnstone. Gulls and terns are common on estuarine and marine beaches and banks, including the laughing gull, herring gull, great black-backed gull, least tern, common tern, and royal tern. The black skimmer is also common on estuarine and marine beaches and nearshore shallows.

An important colonial wading bird rookery is located on Pumpkinseed Island in

lower Winyah Bay. Over 40,000 birds use this rookery annually including white ibis, great egret, snowy egret, cattle egret, little blue heron, glossy ibis, and black-crowned night heron. Feeding areas for the birds nesting on Pumpkinseed Island include intertidal flats, shallows, and impoundments throughout the Winyah Bay area. Particularly important feeding areas are the North Inlet marshes and the perimeter of Mud Bay.

The Winyah Bay estuarine wetlands provide excellent habitat for a variety of raptorial birds including the bald eagle, osprey, peregrine falcon and the marsh hawk. Upland and palustrine wetland habitats provide high quality habitat for other raptors including the great horned owl, barred owl, red-tailed hawk, Cooper's hawk, sharp-shinned hawk, red-shouldered hawk, as well as the bald eagle.

In addition to the birds discussed above a great variety of passerine species may be observed in Winyah Bay habitats. Representatives include various warblers, wrens, sparrows, vireos, and woodpeckers.

b. **Mammals**

Game mammals common in the Winyah Bay area include the white-tailed deer, deer,gray squirrel, fox squirrel, marsh rabbit, cottontail rabbit, and raccoon. The white-tailed deer is most abundant on South Island, Cat Island, and to the east of the bay on Waccamaw neck. The gray and fox squirrels occupy mixed pine-hardwood stands, pine forests, and forested wetland edges. The marsh rabbit is closely associated with estuarine and palustrine wetlands but may be found in various upland habitats where the cottontail is usually more abundant. The raccoon is most abundant near estuarine marshes although it is common in palustrine wetlands and upland habitats.

Important furbearers in the bay area include mink, river otter, beaver, raccoon, grey fox, red fox and opossum. Mink and otter are common in wetland edges of palustrine and estuarine habitats. Foxes utilize upland habitats and wetland edges throughout undeveloped portions of the bay area.

A great variety of nongame mammals are present in Winyah Bay habitats. Among the more notable are the bobcat, least shrew, eastern woodrat, cotton mouse, rice rat, meadow vole, and eastern mole.

c. **Amphibians and Reptiles**

The high degree of upland-wetland habitat interspersion present in the Winyah Bay area provides excellent habitat for a rich variety of herpetofauna. Common amphibians include the dusky salamander, green treefrog, southern chorus frog, American toad, and greater siren. Common reptiles include the American alligator, common snapping turtle, yellow-bellied turtle, eastern diamondback terrapin, five-lined skink, black racer, eastern cottonmouth, and various water snakes of the genus Nerodia.

Several species of sea turtles may occur in coastal waters in and near Winyah Bay. The turtles are described in the section on endangered and threatened species.

2. TERRESTRIAL SYSTEM

a. Existing Land Use

Upland areas on the perimeter of Winyah Bay and its tributary river systems are predominantly forested lands with scattered rural residential and agricultural development. Urbanization is concentrated at Georgetown (1980 population 10,115). Additional clusters of residential and commercial development are present at Maryville, one mile south of Georgetown, and at Belle Isle Gardens located 4 miles south of Georgetown on the western bay shore. Industrial development is presently confined to the immediate port area on the lower Sampit River at Georgetown.

Over nine-tenths of the bay perimeter is occupied by large landholdings as was the case during the plantation era over 100 years ago.

Approximately two-thirds of the Winyah Bay shoreline is occupied by State-owned lands currently protected for wildlife management, education, research, and conservation purposes. The largest tract, the Baruch Institute, occupies 17,500 acres of forest land and tidal marshes comprising most of the eastern bay shoreline. Contiguous to and south of the Baruch Institute is the Yawkey Wildlife Center. The 20,000-acre Center includes the lower one-third of the Winyah Bay shoreline and North and South islands. North Island, forming the north portion of the bay mouth, is managed as a wilderness area and includes 4,500 acres of barrier island beach, maritime forest, and tidal salt marsh habitats. South of the bay mouth are Cat and South islands with over 13,000 acres of tidal marsh, waterfowl impoundments, and maritime forest. The Yawkey Center is an unparalleled refuge for migratory waterfowl, wading birds, and several endangered and threatened wildlife species.

At the head of Winyah Bay above U.S. Highway 17 is the state-owned Samworth Game Management Area including over 1,200 acres of estuarine impoundments managed for waterfowl wintering habitat.

In addition to protected State lands many large private landholdings are present in the Winyah Bay system and are managed primarily as waterfowl hunting preserves. Migratory waterfowl, wading birds, and several endangered or threatened species utilize these private estate lands.

The large area of these undeveloped lands considered together as a resource unit, and the long history of protection from disturbance underscore the significance of the Winyah Bay system as a haven for migratory waterfowl and rare, threatened, or endangered wildlife species.

Ecologically the uplands surrounding Winyah Bay can be separated into two distinct ecosystems: mainland uplands characteristic of the coastal plain, and maritime uplands. Upland areas present on the mainland including Waccamaw Neck and Cat Island support community types characteristic of the South Carolina lower coastal plain. The maritime upland ecosystem is present on the barrier islands, North and South island, forming the mouth of the bay.

b. The Maritime Ecosystem

This system includes the maritime forest and dune systems on North Island and South Island. Also included are the upland communities present on small banks

and bars at the entrance to the bay and at scattered locations in the lower bay. Four distinct vegetative communities have been described (Rayner, 1974; Pinson, 1973; Gaddy, 1977) in the maritime ecosystems of South Carolina and are well developed in the Winyah Bay area. These include the maritime forest, transition shrub, open dunes, and the bird key and bank communities.

1. Maritime forest community

This community type is most extensive on North Island and to a lesser extent on South Island. It occupies the interior dune areas where salt spray from the surf zone is reduced. Canopy tree species include loblolly pine (*Pinus taeda*), live oak (*Quercus virginiana*), palmetto (*Sabal palmetto*), red bay (*Persea borbonia*), magnolia (*Magnolia grandiflora*), and red cedar (*Juniperus virginiana*). Shrub layer species include yaupon holly (*Ilex vomitoria*), red bay, greenbriers (*Smilax* spp.) and palmetto.

2. Maritime transition shrub community

This community occupies a narrow zone between the maritime forest interior and the open dune system. A similar community is found between the maritime forest and the estuarine marshes on the landward side of the barrier islands. The transition shrub community is composed of shrubs, small trees, and vines in a dense tangle. Common plants include wax myrtle (*Myrica cerifera*), yaupon holly, live oak (*Quercus virginiana*), and greenbriers. Near the estuarine marshes this community includes marsh elder (*Iva frutescens*), sea myrtle (*Baccharis halimifolia*), and sea ox-eye (*Borrichia frutescens*).

3. Maritime dune community

The open dune community is present between the surf zone and the maritime forest where exposure to salt spray limits colonization by most tree and shrub species. Open dunes are most extensively developed on North Island. Much of the open dune system has been lost on South Island due to active erosion.

Dominant dune vegetation where dunes are well-developed includes sea oats (*Uniola paniculata*), sea beach panic grass (*Panicum amarum*), sea beach orach (*Atriplex arenaria*), sea rocket (*Cakile harperi*), and creeping spurge (*Euphorbia serpens*).

4. Bird Key and bank community

This community type is present on several small, isolated islands in Winyah Bay and at the bay entrance. These generally exhibit low topography and are frequently subject to storm overwash. Some of the small islands in the bay were originally formed by deposits of dredged sediments from navigation channel maintenance. Vegetative communities include sea beach panic grass, sea oats, marsh hay cordgrass (*Spartina patens*), sandspur (*Cenchrus tribuloides*), and sea purslane (*Sesuvium* ssp.). Tree and shrub species present on higher areas include china-berry (*Melia azedarach*), live oak, sea myrtle, wax myrtle and marsh elder.

AD-A152 525 FINAL ENVIRONMENTAL IMPACT STATEMENT FOR OIL REFINERY GEORGETOWN SOUTH CAROLINA VOLUME 1(U) CORPS OF ENGINEERS CHARLESTON SC CHARLESTON DISTRICT SEP 84 2/5

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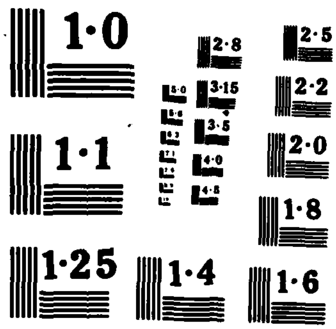

1·0
2·8
2·5
3·15
2·2
3·5
2·0
1·1
4·0
4·5
1·8
1·25
1·4
1·6

c. The Mainland Upland Ecosystem

Prior to extensive disturbance by man's activities Winyah Bay upland areas were probably mixed hardwood and longleaf pine forests (Garren, 1943). Today extensive forested tracts remain over the greater portion of the area. Urban development occupies less than one-tenth of the Winyah Bay perimeter and only minor acreages of agricultural development are present.

The predominant forest type today is pine forest, with mixed pine-hardwood occurring in scattered areas usually adjacent to forested wetlands. Pine forests are represented by three community types: longleaf (*Pinus palustris*), loblolly pine plantations, and loblolly-longleaf communities.

The longleaf community probably developed originally in response to an annual or biennial natural fire regime (Garren, 1943). Longleaf communities are much less prevalent today due to interruption of the natural fire regime and to silvicultural factors. They have been largely replaced by loblolly pine communities due to succession or to silvicultural practices.

The mixed pine-hardwood community occurs today primarily on the perimeter of forested wetland types. Overstory tree species include hickories (*Carya* spp.), water oak (*Quercus nigra*), laurel oak (*Quercus laurifolia*), southern red oak (*Quercus falcata*), sweetgum (*Liquidambar styraciflua*), and black gum (*Nyssa silvatica*). Understory species include wax myrtle, blueberries (*Vaccinium* spp.), American holly (*Ilex opaca*), and greenbriers.

3. WETLANDS OF THE WINYAH BAY SYSTEM

a. Introduction

Wetlands are defined as "lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water" (Cowardin et al., 1979). The functions and values of natural wetland systems are well documented and can be summarized as follows: 1) wetlands are areas of high biological productivity, producing and exporting detrital material important in the estuarine food web; 2) wetlands serve as important nursery grounds for both commercial and recreational fisheries; 3) wetlands store water, provide flood protection, and act as groundwater recharge areas; 4) wetlands provide essential breeding, nesting, and feeding habitats for a variety of wildlife species, including many threatened and endangered species; 5) wetlands act as buffer zones, trapping sediments and filtering pollutants from upland runoff that would otherwise enter valuable aquatic habitats; 6) and finally, wetlands provide recreational and educational opportunities for nature observation and scientific study (Kusler, 1983).

Wetlands are the "life blood" of the estuary, largely responsible for maintenance of high estuarine productivity. Wetlands surrounding the Winyah Bay estuary include forested and non-forested habitats in the estuarine and palustrine ecosystems. These wetlands are depicted in Figure VI.D-1.

b. Estuarine Wetlands

According to Cowardin et al., (1979), estuarine wetlands are tidal wetlands

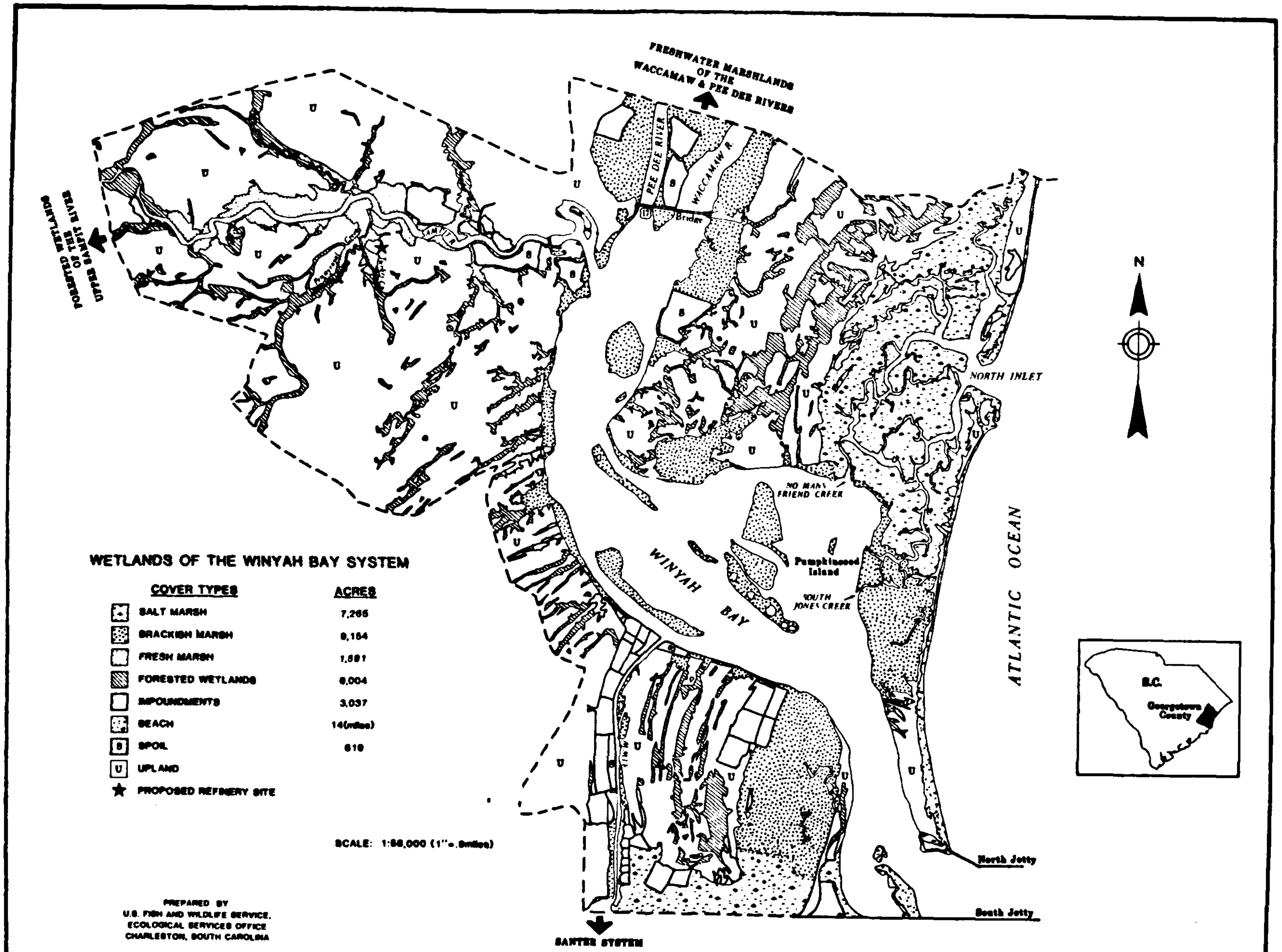

WETLANDS OF THE WINYAH BAY SYSTEM
COVER TYPES
ACRES
SALT MARSH 7,266
BRACKISH MARSH 9,154
FRESH MARSH 1,581
FORESTED WETLANDS 6,004
IMPOUNDMENTS 3,037
BEACH 14(miles)
SPOIL 619
UPLAND
PROPOSED REFINERY SITE
SCALE: 1:56,000
PREPARED BY
U.S. FISH AND WILDLIFE SERVICE,
ECOLOGICAL SERVICES OFFICE
CHARLESTON, SOUTH CAROLINA
FRESHWATER MARSHLANDS OF THE WACCAMAW & PEE DEE RIVERS
FORESTED WETLANDS OF THE UPPER SAMPIT RIVER
SANTEE SYSTEM
PEE DEE RIVER
WACCAMAW R.
Bridge
NORTH INLET
ATLANTIC OCEAN
NO MANS FRIEND CREEK
Pumpkinseed Island
SOUTH JONES CREEK
WINYAH BAY
North Jetty
South Jetty
N
S.C.
Georgetown County

Figure. VI. D-1.

semi-enclosed by land, which have an open, partially obstructed, or sporadic access to the open ocean, and in which ocean water is at least occasionally diluted by freshwater runoff from the land. Within the Winyah Bay system estuarine wetlands include brackish marshes, salt marshes, and brackish impoundments.

1. Brackish marshes

Estuarine wetlands within the bay area are dominated by brackish marshes totalling over 9,000 acres. These brackish marshes form a continuous band of emergent vegetation along the upper and mid-portions of the bay. Slightly north of the U.S. Highway 17 bridge, these brackish marshes merge with the extensive freshwater marshlands of the Waccamaw, Pee Dee and Black rivers. The more seaward brackish marshes of the bay area are dominated by needlerush (Juncus roemerianus) in low areas and giant cordgrass (Spartina cynosuroides) on slightly higher elevations such as creek banks and along upland borders. Scattered smooth cordgrass (Spartina alterniflora) and salt marsh bulrush (Scirpus robustus) are also present. As the freshwater influence increases towards the head of the estuary needlerush marsh decreases and giant cordgrass assumes the dominant role in the marsh community. Associated species include common three square (Scirpus americanus), cattails (Typha spp.), pickerel weed (Pontedaria cordata), and arrowheads (Sagittaria spp.).

2. Salt marshes

Salt marshes within the bay system comprise only 193 acres of emergent wetlands and are limited to scattered island and fringe areas at the mouth of the bay. However, extensive salt marshes totalling 5,640 acres dominate North Inlet estuary which is connected to Winyah Bay via No Mans Friend and South Jones creeks.

Saltmarsh vegetation includes regularly flooded "low marsh" communities dominated by pure stands of smooth cordgrass and irregularly flooded "high marsh" communities characterized by a more diverse assemblage of plant species such as needlerush, marsh-hay cordgrass (Spartina patens), sea ox-eye (Borrichia frutescens), salt grass (Distichlis spicata), glasswort (Salicornia spp.), sea lavender (Limonium spp.), salt marsh fimbristylis (Fimbristylis spadicea) and marsh elder (Iva frutescens) (Tiner, 1977).

3. Brackish impoundments

Approximately 3,000 acres of marshes in the Winyah Bay area have been converted to controlled impoundments primarily to attract migratory waterfowl species. These were formerly rice fields during the eighteenth and nineteenth centuries when rice was an important crop in coastal South Carolina. A variety of management techniques are used in these impoundments to maintain preferred duck food plants and to suppress undesirable vegetation. Brackish impoundments are primarily maintained through precise manipulations of water levels and salinity regimes and are managed for duck food plants such as widgeon grass (Ruppia maritima), saltmarsh bulrush, dwarf spikerush (Eleocharis parvula), muskgrass (Chara hornemannii), and sea purslane (Sesuvium maritimum) (Phil Wilkinson, S.C. Wildlife and Marine Resources Department, personal communication).

c. **Palustrine Wetlands**

Palustrine wetlands are defined as "all nontidal wetlands dominated by trees, shrubs, persistent emergents, non-aquatic mosses or lichens, and all such wetlands in tidal areas where salinity due to ocean-derived salts is below 0.5 parts per thousand" (Cowardin et al., 1979). Within the Winyah Bay system palustrine wetlands include freshwater marshes, freshwater impoundments, and forested wetlands.

1. **Forested wetlands**

Forested wetlands in the bay area include two distinct communities: bald cypress-water tupelo and pond cypress-swamp tupelo communities. The pond cypress-swamp tupelo community is found in linear depressions or "bays" between old beach dune ridges that surround Winyah Bay. These depressions are characterized by high water tables and soils that are generally saturated for extended periods throughout the year. Dominant overstory trees are usually swamp tupelo (Nyssa sylvatica var. biflora) and pond cypress (Taxodium distichum var. nutans). Slightly drier sites may include red maple (Acer rubrum), sweet gum (Liquidambar styraciflua) and ash (Fraxinus sp.). A moderately dense shrub layer with both evergreen and deciduous species is common in this community, while ferns and vines dominate the herbaceous layer. Typical shrub and herbaceous layer species include wax myrtle (Myrica cerifera), red bay (Persea borbonia), fetter-bush (Lyonia lucida), blackberry (Rubus spp.), poison ivy (Rhus radicans), greenbriars (Smilax spp.), netted chain fern (Woodwardia areolata) and cinnamon fern (Osmunda cinnamomea).

The bald cypress-water tupelo community is seasonally to semipermanently flooded and occurs primarily within the floodplains of the major rivers and tributaries feeding Winyah Bay. This community may also be found in "bays" subjected to longer seasonal flooding than pond cypress-swamp tupelo "bays" and in scattered freshwater impoundments around Winyah Bay. Bald cypress (Taxodium distichum) and water tupelo (Nyssa aquatica) dominate the canopy with occasional red maple, swamp cottonwood (Populus heterophylla), and swamp tupelo. Carolina ash (Fraxinus caroliniana) generally dominates the subcanopy layer. Associated species include storax (Styrax americana) and water elm (Planera aquatica), as well as immature canopy species. Frequent flooding limits the shrub layer to a few species such as Virginia willow (Itea virginica) and buttonbush (Cephalanthes occidentalis), and the herbaceous layer to aquatic and emergent species such as duckweeds (Lemna spp.), mermaidweed (Proserpinaca pectinata), bur-reed (Sparganium americanum) and lizard's tail (Saururus cernuus).

2. **Freshwater tidal marshes**

Tidal emergent wetlands are prevalent north of Winyah Bay in the lower reaches of the Black, Pee Dee and Waccamaw rivers where salinities drop below 0.5 parts per thousand. These wetlands are predominantly "abandoned ricefields" that have succeeded into freshwater emergent marshes. Diversity of plant species in these unimpounded freshwater marshes is higher than in any other wetland community in the Winyah Bay area. Tiner (1977) listed eighteen plants commonly occurring in the freshwater marshes of the Winyah Bay system and over 100 plants characteristic of tidal freshwater marshes of South Carolina. Unlike salt and brackish marshes in which one or two species dominate year round, freshwater

marsh species exhibit seasonal dominance patterns. In the Winyah Bay area a typical seasonal progression begins in early spring to summer months with colorful, showy plants such as pickerel weed, arrowheads, arrow-arum (Peltandra virginica), spider lily (Hymenocallis occidentalis) and golden-club (Orontium aquaticum). As the season progresses, needle-leaved grasses, sedges and cattails such as giant cutgrass, giant cordgrass, softstem bulrush (Scirpus validus), sawgrass (Cladium jamaicense) and broadleaf cattail (Typha latifolia) bloom and dominate mid-summer months. And finally, late summer months are dominated by smartweeds (Polygonum spp.) and fall sedges and grasses such as woolgrass (Scirpus cyperinus) and panic grass (Panicum spp.).

3. Freshwater impoundments

Freshwater impoundments are scattered throughout the lower Black, Pee Dee, and Waccamaw rivers. These areas are primarily managed for waterfowl but may be used for cattle pasturage, snipe hunting, or planting cypress (Morgan et al., 1975). Management techniques used to maintain these freshwater impoundments include water level manipulations and prescribed burnings. In extreme cases herbicidal treatments and mechanical crushing are being used to control undesirable plant species such as common reed (Phragmites communis). Freshwater impoundments generally are managed for smartweeds, wild millet (Echinochloa crusgalli), red root (Lachnanthes caroliniana), wild rice, white water lily (Nymphaea odorata), soft stem bulrush, and asiatic dayflower (Aneilema keisak) (Tiner, 1977).

4. ECOLOGY OF WINYAH BAY

a. Introduction

Estuaries and associated tidal marshes are among the most productive natural systems in the world. Since almost all coastal finfish and shellfish species of recreational and/or commercial importance are dependent upon the estuaries for some phase of their life cycle, man directly reaps the benefit of this high productivity through harvest of these species. Indeed, it has been postulated that for each acre of estuary destroyed there could be a corresponding annual loss in yield of about 535 pounds of fisheries products on the Continental Shelf (Stroud, 1971).

Although it is easiest for the layperson to think of estuaries strictly in terms of production of commercially and recreationally important species, this view tends to become somewhat myopic. In order to tackle the problem of impact assessment at the estuary level, it is important to gain some insight into the complex biological and chemical pyramid of support that exists for the generally high trophic level commercially and recreationally important species.

At a fundamental level, there are three principal kinds of organisms in functioning ecological systems: plants, animals and bacteria. Their interdependent relationships are trophic (that is, relating to nutrition) and make up the cycling of carbon, nutrients and energy flow upon which system functioning is based. These living components of the community plus the physiochemical environment with which they interact constitute an ecosystem. Green plants are autotrohpic or primary producers which, through the process of photosynthesis, can utilize sunlight energy to build up complex organic

substances (sugars, starches, oils, etc.) from carbon dioxide and water. All other living organisms, including most animals and decomposers (bacteria and fungi), are termed heterotrophic organisms and depend upon the metabolizeable forms of carbon produced by the green plants for their nutrition. The animal component of the heterotrophs are called consumers and may be either herbivores (feeding directly on plant tissues), detritivores (feeding on dead plant materials and decomposers) or carnivores (feeding on other consumers). The decomposers foster perpetuation of chemical and energy cycles by breaking down the complex organic materials of dead plants, dead animals, and animal excreta into simpler chemical substances such as soluble inorganic salts, which are then suitable for uptake by green plants.

In estuaries such as Winyah Bay primary producers are represented by rooted angiosperms (higher plants such as marsh grasses), benthic algae and phytoplankton. The produced energy is transferred through food chains in two manners (Odum, 1971): 1) a grazing food chain, involving transfer of energy from living plants to animals, and 2) a detritus food chain, involving transfer of energy from plants to animals via organic detritus. Food chains are variously interconnected, often in complex patterns, to form what is referred to as a food web.

A generalized estuarine food web is presented in Figure VI.D-2. Energy is transferred through the estuarine food web from detritus and its associated decomposer microbiota to higher trophic levels largely through bottom-dwelling invertebrates and detritus-feeding fishes, and from phytoplankton, macrophytes and benthic algae to grazers, including benthic invertebrates, zooplankton and certain fishes. Middle carnivores include larger nektonic (free-swimming) species and zooplankton predators. Top carnivores include larger fishes, predatory birds and mammals, including man.

Classically, the scientific literature claims that southeast estuaries are based to a greater degree on detritus food chains than on grazing food chains (Odum and de la Cruz, 1967; Darnell, 1967). However, recent studies employing stable carbon isotope techniques suggest that the phytoplankton grazing food web may be more important in estuaries than previously thought (Hughes and Sherr, 1983; Haines, 1976a, b, 1977; Haines and Montague, 1979).

"The vast size and dynamic nature of Winyah Bay renders any comprehensive ecological investigation of physical, chemical and biological characteristics of the estuary an impossible task" (Allen et al., 1982). Nevertheless, with this limitation in mind, the following section will attempt to summarize the available data on the aquatic system of Winyah Bay in order to present a baseline framework from which to project and assess impacts related to construction and operation of the CRDC refinery. The section is generally organized trophically (i.e., starting with producers and progressing through consumer groups), and information gaps are identified within the text. Information on macrophytic producers (vascular plants) can be found in the Wetland Section of this document.

b. Phytoplankton and Microbenthic Algae

Phytoplankton represent a high proportion of the standing crop of primary producers in estuaries and salt marsh creeks. They are microscopic aquatic plants which are primarily transported by tidal and wind driven currents. No quantitative or qualitative work on the phytoplankton or microbenthic algae

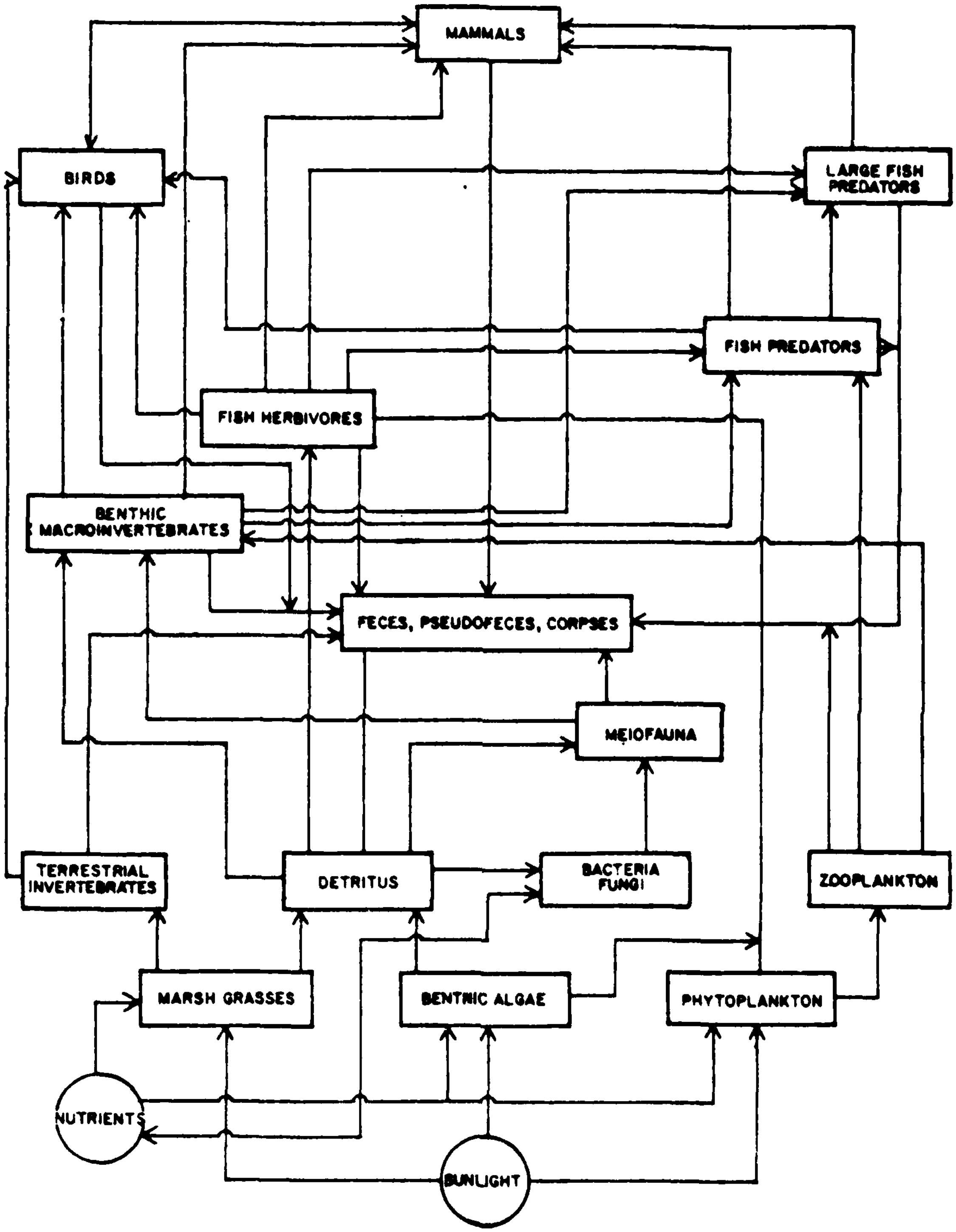


Figure VI.D-2
Generalized Estuarine Food Web
(from Sandifer et al., 1980)

of Winyah Bay could be found. Indeed, taxonomic studies of estuarine phytoplankton in the State of South Carolina are not numerous. However, a listing of species identified or suspected from coastal South Carolina can be found in Manzi and Zingmark (1978) and Sandifer et al. (1980).

Estuarine, salt marsh and coastal marine phytoplankton belong to several plant divisions including Cyanophyta, Chlorophyta, Euglenophyta, Baccillariophyta, Chrysophyta, Cryptophyta and Pyrrhophyta. Benthic microalgae primarily belong to the Divisions Cyanophyta and Chlorophyta, while dominant members of the estuarine phytoplankton community include species of the Divisions Baccillariophyta (diatoms) and Pyrrophyta (dinoflagellates).

Pelagic phytoplankton refer to species found in the water column, while benthic phytoplankton are associated with the bottom. Recent work has demonstrated that ultraplankton and nano-plankton, which are the smallest of the plankton, and phytoneuston (plankton located at or near the air/water interface) contribute a disproportionately large share to the total primary productivity (Van Valkenburg and Flemer, 1974; Manzi et al., 1977). This latter group is particularly noteworthy since it would be the first phytoplanktonic component affected by petroleum spills.

A wide array of both natural and man-induced factors affect estuarine phytoplankton. These have been summarized by Rice and Ferguson (1975) (Table VI.D-1). Despite these wide fluctuations in environmental factors, estuaries provide a highly productive environment for phytoplankton. Zingmark (1977) estimated the annual rate of benthic algal production in the adjacent North Inlet system's estuarine mudflats to be two orders of magnitude (100x) larger than values determined for an intertidal sandy beach.

Assessments of Chlorophyll "a" concentrations, which reflect the total standing crop of phytoplankton present in the water, were used as indicators of primary productivity in creeks connecting Winyah Bay with the North Inlet system by Allen et al. (1982). Phytoplankton standing crop exhibited a bimodel pattern with peaks occurring in late summer and winter. The absence of a large spring phytoplankton bloom was thought to be a reflection of the sampling regime. Marshall (1980) described a bimodel pattern, with fall and spring phytoplankton population peaks, for lower Chesepeake Bay and an associated salt marsh intertidal creek. Creek waters had a greater assortment of flagellates, smaller diatoms typically associated with mudflats and vegetation within the creek complex, and representatives of other phytoplankton taxa.

EAF (1982) analyzed phytoplankton production in Winyah Bay through use of light and dark bottles and radioactive tracer techniques. However, emphasis was on a determination of the effects of the International Paper discharge plume and little can be gleaned regarding phytoplankton dynamics in Winyah Bay as a whole from this study.

The second year of Winyah Bay sampling cruises by the Belle W. Baruch Institute for Marine Biology and Coastal Research included Chlorophyll "a" values. An analysis of the results should be ready by the Final EIS stage and any significant findings will be included in that document.

c. <u>Zooplankton</u>

Zooplankton are microscopic animals which are carried more or less passively by

Table VI.D-1. Natural and man-imposed conditions which determine levels and rates of change of factors affecting abundance and succession of estuarine phytoplankton (Rice and Ferguson, 1975).

Factors	Natural Conditions	Man-imposed Conditions
Salinity	Precipitation, runoff, evaporation, circulation of water	Water impoundment, channelization, dredge and fill, mosquito ditching
Temperature	Latitude, season, weather, time of day, circulation of water	Heated effluent, dams, canals and waterways, stream channelization
Light Intensity		
At surface	Latitude, season, weather, time of day	Air pollution - smog
Below surface	Reflection, absorption, scattering	Dredging, waste dumping, erosion
Nutrients	Drainage, runoff, circulation of water, sediments	Sewage and industrial wastes, urban and agricultural drainage, erosion
Metabolites	Living and dead plants and animals	Sewage, urban and agricultural drainage, erosion
Toxic Substances		
Petroleum	Deposits	Leads and spills during drilling, transport, storage, use of disposal
Radionuclides	Primordial deposits, cosmic-ray produced	Fallout, nuclear power reactors, other releases
Heavy Metals	Terrestrial deposits, sediments, land drainage	Industrial and domestic wastes, mining, erosion
Synthetic Toxicants		Industrial,agricultural, domestic use

water currents. This community represents a diverse assemblage of organisms containing members from many invertebrate phyla as well as egg and larval stages of fish. Holoplankton are those members of the community which permanently reside in the water column, while meroplankton represent those organisms who only spend a portion of their life cycle (usually the larval stage) in the plankton.

Zooplankton biomass is strongly related to phytoplankton biomass (Cornita and Anderson, 1959; McCauley and Kalff, 1981; Toner, 1981). However, zooplankton also exhibit detritivorous and carnivorous feeding behavior (Cooper and Goldwan, 1980; Pearre, 1981), feeding on dead organic particles or the layers of decomposer organisms surrounding such particles and on smaller zooplankton. Many species are generalists and will switch feeding behavior, depending upon which food sources are most available.

Zooplankton biomass and numbers are usually greater in estuaries than in any other aquatic habitat, reflecting the overall high productivity of the estuarine environment (Sandifer et al., 1980). Although primarily of marine origin, estuarine zooplankton also includes groups originating from freshwater and terrestrial ancestors (Green, 1968).

The zooplankton form a vital link in the estuarine food web, transferring energy from phytoplankton or detritus production to higher trophic levels such as fish and shellfish. Most commercially important fish and shellfish have young or larval stages which are members of, and predators on, the zooplankton community. Adults of most species feed directly on zooplankton or on species that do. For many species that depend on estuaries as spawning or nursery grounds (e.g., Atlantic croaker, Atlantic menhaden, seatrout, drum, blue crab and white shrimp), an abundant zooplanktonic population is a necessity (Sandifer et al., 1980). Crustaceans and fishes which begin life as planktonic eggs or larvae usually remain in the water column for days or weeks until they reach later developmental stages which require a more bottom-oriented lifestyle typical of the adults of those species. These young forms often continue to feed on smaller zooplankton but are themselves known as motile epibenthos.

Because of both spatial and temporal patchiness, as well as wide size ranges, characterization of any zooplankton community is difficult and requires a complex sampling regime. The results from the first year of a two years' sampling effort in Winyah Bay are presented in Allen et al. (1982). Zooplankton concentrations and constituents varied considerably throughout the bay, both temporally and spatially. Lower bay stations displayed consistently more diverse and abundant zooplankton assemblages.

Lower and upper bay stations also differed in the number of dominant species. The lower bay was characterized by more species of abundance, several of which were copepods including *Acartia tonsa*, *Parvocalanus crassirostris*, *Pseudocalanus coronatus*, *Oithona colcarva* and *Euterpina acutifrons*. In the upper bay, rarely more than four species were ever abundant; however, some of these upper bay abundant forms (particularly *Eurytomora affinis* and several cladocerans, or water fleas) did not occur, or were rare, in the lower bay. Many forms, especially meroplankton, appear to be more or less restricted to the lower bay stations. Salinity is the dominant environmental factor controlling the distribution of various species within the estuary.

As in other locations on the southeast coast, numbers of zooplankton were greater in the warm months (April-September) and were reduced by as much as an

order of magnitude in the winter (November-March). Densities of meroplankton in particular decreased in the winter months, except for barnacle nauplii and polychaete larvae. Only Acartia tonsa and barnacle nauplii were relatively common at all stations during most times of the year. In the second year of the Winyah Bay study, the copepod Acartia tonsa accounted for more than 60% of all zooplankton collected in the bay. Mean densities exceeded 20,000/m^3 at most stations, especially in summer.

Within the limits of the information gathered to date it appears that the zooplankton assemblages of the upper and lower bay are obviously different. Diversity and abundance are almost always greatest near the ocean during the warm months. Relatively few species occur in both the upper and lower bay stations, and the zooplankton community of the lower bay closely resembles that of nearshore coastal and North Inlet environments. During periods of major freshwater inflow, many copepod and cladoceran species characteristic of the rivers are introduced to the upper bay. This most often occurs in the winter. Differences between the upper and lower bay zooplankton are greatest during such an event.

d. Benthic Organisms

Benthos are those organisms attached or resting on the bottom (epifauna) or living in the bottom sediments (infauna). Several species directly harvested on a commercial or recreational basis (i.e., shrimp, crabs, oysters, clams) are components of the benthic community in adult and/or larval life cycle stages. The majority of benthic organisms play an essential role in transference of energy through the estuarine food web. This secondary production is accomplished through either deposit (consumption of detrital materials) or suspension (filter) feeding mechanisms, and the resultant biomass is harvested by higher trophic level predators, many of which are fish of commercial and recreational importance or trophic intermediaries to these species.

Benthic communities are also important as indicators of pollution (McIntyre and Holme, 1971). It has also been recently hypothesized (Dame et al., 1980) that the filter feeding component of the benthic community may represent a major coupling and a major controlling component in the cycling of nutrients and flow of energies in some estuaries.

1. Benthic infauna

Only two studies are available that deal with benthic infauna in segments of Winyah Bay. There is no infaunal data available for the upper Winyah Bay system (Pee Dee and Waccamaw River mouths) or the Mud Bay vicinity. The EAF (1982) took core samples at several stations in the Sampit River (see Sampit River section) and a few stations in Winyah Bay between Mud Bay and the Sampit River from May, 1980 through July, 1981. The samples were dominated by two polychaete species, one oligochaete, one cnidarian and one amphipod species. Diversity of the community (a greater number of component species) generally increased with distance from the Sampit River mouth.

Hinde et al. (1981) sampled 12 stations in and around lower Winyah Bay and the Winyah Bay entrance channel during October, 1980. They found that salinity regime and sediment type were the dominant factors in determining infaunal community composition. The greatest infaunal species diversity occurred at

sandy offshore stations, where the stable salinity regime and absence of continual stress imposed by a physically rigorous environment have allowed diversification of the fauna on an evolutionary time scale. Conversely, the harsher environments of the middle and upper reaches of lower Winyah Bay are characterized by fewer infaunal species which are tolerant of natural environmental variation.

Although Hinde et al. (1981) gives a general insight into some areas of Winyah Bay infauna, it should be kept in mind that the sampling was performed during only one month, October, when biological activity is past the annual peak. Although the general precepts of Sanders (1968) "biological accommodated" community in the ocean reach and "physically controlled" communities in the bay proper may hold true, a year-round study would be necessary to confirm this hypothesis.

As mentioned earlier, no data is available for infaunal assemblages in Mud Bay. However, exploratory grabs in this area reveal an extremely rich infaunal community of low diversity, dominated by polychaete worms and softshell clams (Dennis Allen, Baruch Marine Lab, personal communication). This would fit in well with the reported importance of Mud Bay as a fishery feeding area and overwintering area for the bottom-feeding endangered shortnose sturgeon because infauna tend to be soft and succulent and form an important source of food for bottom-feeding fish which can either extract them from the sediment or snap off portions which may extend above the surface (Holme and McIntyre, 1971).

2. Benthic epifauna

Benthic epifauna was sampled in the Winyah Bay system by Hinde et al., 1981; Wenner et al., 1981; EAF, 1982; and Allen et al., 1982. The latter study represents the most detailed effort towards description of the motile epifaunal component of the Winyah Bay system. However, the observations presented below from Allen et al. (1982) represent only preliminary analyses based primarily on the first year's sampling of a two-year study. Mysids, dominated by *Neomysis americana*, were the most abundant motile epibenthic organisms sampled at all stations. Other prevalent species collected included gammarid and caprellid amphipods, cumaceans, isopods, decapod shrimp larvae and juveniles, crab megalopae, chaetognaths and fish larvae.

Mysids, or opossum shrimp, occurred year-round but were most abundant during the warmest months. Mysids constituted an important component of the motile epifauna at all stations. Gammarid amphipods were found in higher densities at river stations than lower bay stations. Caprellid amphipods and cumaceans, most commonly found at stations closest to the ocean, exhibited relatively low densities throughout the bay. Highest densities of isopods consistently

occurred at the high salinity end of the estuary. Densities of decapod shrimp larvae and juveniles were highest from June through September. Penaeid shrimp larvae were common in the river collections. Crab megalopae were most abundant from June through September. Lower bay stations yielded megalopae of a variety of crab species, while the river stations were dominated by fiddler crab (Uca spp.) megalopae. Chaetognaths, or arrow worms, often dominated the catches at the lower bay stations, with maximum densities occurring near the ocean during the summer months.

Fish larval densities were highest in August, March and June. Lower bay collections included sciaenids, anchovies and gobies. Croaker larvae were collected at most stations in November and December. Young-of-the-year spot, summer and southern flounder, speckled worm and American eel, and pinfish larvae occurred at most stations during the winter. In addition to these species, March samples contained pipefish and clupeid (herring) larvae, the latter group most common at river stations. In June, fish larval diversity increased considerably with whiting, silver perch, star drum, hogchoker, goby, blenny and anchovy larvae collected throughout the estuary. Dozens of other less familiar marine fish larvae were found at various locations in Winyah Bay during the warm months. Highest densities of fish larvae occurred in lower to mid bay stations, particularly in the Mud Bay vicinity.

Besides groups of organisms that represent larval and juvenile stages of species of direct commercial and recreational importance (i.e., decapod and fish larvae and juveniles), the epibenthic community consists of organisms which constitute major sources of food for juvenile fishes. These include isopod, amphipod, cumacean, and mysid crustaceans, as well as a variety of small decapod shrimps and crabs.

It is important to note that many components of the epibenthic community of the bay were not adequately sampled by the techniques employed in this study. Sled catches probably underestimate numbers of cumaceans and certain amphipods which are closely associated with the bottom. Station location in the relatively deep channels and open waterways precluded capture of the majority of fish larvae which are more abundant in shallow water and marsh creeks. The fish life cycle stage sampled by this study represents a late-larval/pre-juvenile stage which typically will leave the water column for an epibenthic existence. Larger, faster swimming crustaceans and fishes avoid the sampling device, but based on the numbers collected there are relatively high densities of a large variety of small motile organisms associated with the bottom of Winyah Bay.

e. Shellfish

1. **Decapod crustacea**

Trawl studies of the Winyah Bay system (EAF, 1982; Wenner et al., 1981; Hinde et al., 1981) revealed an abundance of blue crabs (Callinectes sapidus), pink shrimp (Penaeus duorarum), brown shrimp (Penaeus aztecus), and white shrimp (Penaeus setiferus). Other decapod crustacea, of less direct recreational and commercial importance, that appeared in trawl samples of the bay are listed in Table VI.D-2.

Wenner et al. (1981) found blue crabs throughout the Winyah Bay system. However, catches were greatest in the mid-bay area from September to December. Penaeid shrimp were limited seasonally but not spatially in occurrence. Pink and white

Table VI.D-2. Ranking by numerical abundance for species of decapod crustaceans collected from Winyah Bay during October, 1980 (Hinde et al., 1981).

Species	Total Number	Percent of Catch	Cumulative Percent
Penaeus setiferus	1694	41.91	
Callinectes sapidus	727	17.99	59.90
Portunus gibbesii	681	16.85	76.75
Portunus spinimanus	364	9.01	85.76
Penaeus duorarum	190	4.70	90.46
Trachypenaeus constrictus	77	1.90	92.36
Ovalipes stephensoni	55	1.36	93.72
Panopeus herbsti	51	1.26	94.98
Penaeus aztecus	43	1.06	96.04
Callinectes ornatus	37	0.92	96.96
Ovalipes ocellatus	36	0.89	97.85
Callinectes similis	30	0.74	98.59
Palaemonetes vulgaris	17	0.42	99.01
Libinia dubia	9	0.22	99.23
Hepatus epheliticus	7	0.17	99.40
Neopanope sayi	6	0.15	99.55
Arenaeus cribrarius	5	0.12	99.67
Pagurus longicarpus	3	0.07	99.74
Pagurus pollicaris	3	0.07	99.81
Libinia emarginata	2	0.05	99.86
Libinia sp.	2	0.05	99.91
Menippe mercenaria	2	0.05	99.96
Persephona mediterranea	1	0.02	99.98
TOTAL	4042		

shrimp were most numerous in September and October, while brown shrimp were most plentiful during July and August. All three species were plentiful at stations throughout Winyah Bay.

Hinde et al. (1981) reported that both blue crabs and penaeid shrimp follow classic life history estuarine movements in Winyah Bay. Penaeid shrimp spawn in offshore waters and post-larvae enter the estuarine nursery grounds and usually concentrate in shallow waters. With growth, the juveniles migrate to deeper, higher salinity portions of the estuary before returning to sea to spawn.

Blue crab adult males remain in brackish waters year round, while adult females move downstream during September and October and to the deepest portions of the lower estuary as the weather gets colder. In spring these females migrate to the nearshore beaches and peak spawning occurs in late May and early June. Larval stages enter the estuarine nursery as zooplankton and mature in the estuary. Crab zoea larvae were abundant throughout the Winyah Bay system, including the low salinity river mouths, from June through September (Allen et al., 1982), confirming the completed life cycle picture in Winyah Bay.

2. Molluscs

There is no significant oyster or clam resource in Winyah Bay proper. The bay is currently closed to molluscan shellfish harvesting and the resource is limited to low quality intertidal oysters near the mouth (Conservation Foundation, 1980). The absence of molluscan shellfish in Winyah Bay is not a new phenomenon as evidenced by this 1890 survey account (Battle, 1892): "Winyah Bay formed by the junction of the Pee Dee, Black, and Waccamaw Rivers, is totally unsuitable for oyster cultivation, on account of the quantity of fresh water flowing into it from these rivers." With regards to Mud Bay, Battle (1892) concludes that it "...is entirely too fresh for the cultivation of oysters, to say nothing of the unsuitable character of the bottom. This limits the ground to that portion of the various creeks which flow through the marshes between the bay and North Inlet, where favorable conditions may be found."

A State Shellfish Ground exists in a portion of North Island, specifically portions of Jones and tributary creeks. The upper portion of this area is open to shellfish harvesting, although the majority of the area is currently closed to harvesting due to pollution from Georgetown. A shellfish survey of the closed area performed by the Office of Conservation, Management and Marketing of the S.C. Wildlife and Marine Resources Department reports a substantial clam and oyster resource in this area.

The creeks in the North Inlet system support a significant and abundant oyster and clam resource (Dennis Allen, Baruch Marine Lab, personal communication). The portions of North Inlet under control of the Baruch Foundation have been reported to support the "healthiest" shellfish resource in the State with virtually no coliform contamination (Luke Hause, S.C. Department of Health and Environmental Control, personal communication).

f. Finfish

Relatively few fisheries studies have been performed in Winyah Bay. EAF (1982) trawled one Sampit River and four mid-bay stations from May, 1980 through July, 1981. Dominant fishes included the Atlantic croaker (Micropogonias

undulatus), bay anchovy (Anchoa mitchilli), spot (Leiostomus xanthurus) and weakfish (Cynoscion regalis). These species were seasonally distributed within the estuary.

Wenner et al., (1981) sampled nine trawl stations monthly from January, 1977 to December, 1978. The stations were located in the channel of the Winyah Bay estuary and ranged from the mouth of the bay to the freshwater reaches of the four rivers feeding the bay. A total of 70 species of fishes was collected with seven species comprising more than 90% of the total numbers. These numerically dominant species were star drum (Stellifer lanceolatus), Atlantic croaker, hogchoker (Trinectes maculatus), white catfish (Ictalurus catus), weakfish, Atlantic menhaden (Brevoortia tyrannus) and spot. A complete qualitative list of fish sampled in this study is included as Table VI.D-3.

From this data, it appears that the Winyah Bay estuarine system is similar in species composition to other southeastern United States estuaries which receive considerable freshwater input and are usually dominated by euryhaline species which primarily use the estuary as a nursery ground.

Both spatial and temporal variation among fish species was noted in the Wenner study. Spatial variation was largely due to salinity. Stenohaline marine species were generally restricted to the lower bay, while species found in the upper reaches (lower river areas) included predominantly freshwater species, transients and catadromous and anadromous species. Those stations characterized by unstable yet generally high salinity were the richest in species composition and supported the most individuals, while fewest species and individuals were collected at stations on the Black, Pee Dee and Waccamaw rivers which exhibited lower and more stable salinities. This is apparently a common phenomenon in estuaries attributable to a diverse assemblage of stenohaline marine species and euryhaline species.

Temporal variations among species were due to migratory patterns, generally established by life-cycle requirements. Fish use estuarine waters in several different ways. Anadromous species such as the herrings, shads and sturgeons spawn in fresh water. The young generally browse in the rivers and estuary during their first summer and spend the next 3 to 4 years in the open ocean. Young sturgeon are more estuarine dependent and spend 3 to 4 years in the rivers and estuaries before migrating to the ocean. Another common pattern typified by croaker, weakfish, flounder, drum and menhaden is spawning in the nearshore environment with larval and postlarval movement into the low salinity areas of the estuarine nursery where they have an abundant food source and are afforded protection from predators. Even many of the species that typically spend the majority of their life-cycle offshore, such as bluefish, move into the estuaries to feed. Some undertake regular seasonal feeding forays into estuaries. All of the above patterns of use exist simultaneously as each species follows its own seasonal sequence.

Limitations of the above trawl studies are related to the sampling bias of the otter trawl gear which emphasizes capture of juveniles and selectively samples channel reaches, excluding tidal creeks, shallow flats, and nearshore marsh habitat. Several commercially important species, particularly shad and sturgeon, are not readily vulnerable to this gear and hence were probably not adequately sampled. Even flatfishes such as flounders and rays which are slow moving, bottom species are not effectively sampled with this gear. Also, species such as tarpon (Megalops atlantica), ladyfish (Elops saurus), Spanish mackerel (Scomberomorus maculatus), gag grouper (Mycteroperca

Table VI.D-3. Fish species sampled from 1977-1978 in Winyah Bay trawl study. Species are listed in order of abundance (Wenner et al., 1981).

Stardrum	*Stellifer lanceolatus*
Atlantic croaker	*Micropogonias undulatus*
Hogchoker	*Trinectes maculatus*
White catfish	*Ictalurus catus*
Weakfish	*Cynoscion regalis*
Atlantic menhaden	*Brevoortia tyrannus*
Spot	*Leiostomus xanthurus*
Spotted hake	*Urophycis regia*
Blackcheek tonguefish	*Symphurus plagiusa*
Bay anchovy	*Anchoa mitchilli*
Silver perch	*Bairdiella chrysoura*
Southern flounder	*Paralichthys lethostigma*
Southern kingfish	*Menticirrhus americanus*
Bighead searobin	*Prionotus tribulus*
Summer flounder	*Paralichthys dentatus*
American eel	*Anguilla rostrata*
Harvestfish	*Peprilus alepidotus*
Oyster toadfish	*Opsanus tau*
White perch	*Morone americana*
Atlantic spadefish	*Chaetodipterus faber*
Northern searobin	*Prionotus carolinus*
Striped bass	*Morone saxatilis*
Southern hake	*Urophycis floridana*
Feather blenny	*Hypsoblennius hentzi*
Longnose gar	*Lepisosteus osseus*
Atlantic stingray	*Dasyatis sabina*
Skillet fish	*Gobiesox strumosus*
Channel catfish	*Ictalurus punctatus*
Butterfish	*Peprilus triacanthus*
Windowpane	*Scophthalmus aquosus*
American shad	*Alosa sapidissima*
Atlantic sturgeon	*Acipenser oxyrhynchus*
Fringed flounder	*Etropus crossotus*
Threadfin shad	*Dorosoma petenense*
Brown bullhead	*Ictalurus nebulosus*
Bay whiff	*Citharichthys spilopterus*
Redear sunfish	*Lepomis microlophus*
Pinfish	*Lagodon rhomboides*
Bluefish	*Pomatomus saltatrix*
Ocellated flounder	*Ancylopsetta quadrocellata*
Spotted seatrout	*Cynoscion nebulosus*
Striped mullet	*Mugil cephalus*
Striped cusk-eel	*Ophidion marginatum*
Atlantic bumper	*Chloroscombrus chrysurus*
Gafftopsail catfish	*Bagre marinus*
Striped burrfish	*Chilomycterus schoepfi*
Warmouth	*Lepomis gulosus*
Blueback herring	*Alosa aestivalis*

Table VI.D-3. (Concluded)

Lookdown	Selene vomer
Striped searobin	Prionotus evolans
Southern stargazer	Astroscopus y-graecum
Flat bullhead	Ictalurus platycephalus
Carp	Cyprinus carpio
Freshwater goby	Gobionellus shufeldti
Freckled blenny	Hypsoblennius ionthas
Red drum	Sciaenops ocellata
Black drum	Pogonias cromis
Leopard searobin	Prionotus scitulus
Planehead filefish	Monacanthus hispidus
Gray snapper	Lutjanus griseus
Snook	Centropomus sp.
Sea catfish	Arius felis
Spotted sunfish	Lepomis punctatus
Speckled worm eel	Myrophis punctatus
Striped anchovy	Anchoa hepsetus
Gizzard shad	Dorosoma cepedianum
White bass	Morone chrysops
Sheepshead	Archosargus probatocephalus
Black sea bass	Centropristis striata
Rock sea bass	Centropristis philadelphica
Northern pipefish	Syngnathus fuscus
Shortnose sturgeon	Acipenser brevirostrum
Clearnose skate	Raja eglanteria
Smoothead scorpion fish	Scorpaena calcarata
Banded drum	Larimus fasciatus
Corger eel	Ariosoma balearicum
Redbreast sunfish	Lepomis auritus
Largemouth bass	Micropterus salmoides

microlepis), cobia (Rachycentron canadum), Jack crevalle (Caranx hippos) and several species of shark which are known to occur in Winyah Bay (Glenn Ulrich, S.C. Wildlife and Marine Resources Department, personal communication) were not sampled by the study.

In this regard, the relatively fewer species and individuals sampled in the lower salinity stations on the Black, Pee Dee, and Waccamaw rivers should not be interpreted as representing a reduction in the fisheries values of these areas. In contrast, the low salinity portion of estuaries is a region of exceptional value to fish (Cronin et al., 1971). It is this region that receives fish eggs, larvae, and young from freshwater spawners, semi-anadromous and anadromous fish, estuarine spawners and some of those species that spawn in the lower estuary or ocean. Some species, notably drums, flounders and white shrimp, migrate directly to low salinity estuarine nurseries (Weinstein, 1979).

The importance of tidal salt marshes as a nursery habitat has been well documented for several southeastern estuaries (Weinstein, 1979; Cain and Dean, 1976; Shenker and Dean, 1979; Bozeman and Dean, 1980; Turner and Johnson, 1972). The EAF (1982) supplemented their Winyah Bay trawl data with three marsh creek seine stations; one along the western shoreline of mid-Winyah Bay, one at the mouth of the Pee Dee River and one in the Sampit River, approximately 6 miles upstream from its confluence with Winyah Bay proper. Seasonal variation was evident at all stations, with the highest numbers of species and individuals noted during spring and fall. Dominant species included top minnows, sciaenids, blue crabs, and palaemoneid and penaeid shrimps.

The North Inlet estuarine system which connects and exchanges with Winyah Bay in the vicinity of Mud Bay (Kjerfve, 1978) is one of the most intensively studied saltmarsh ecosystems in the world (Allen et al., 1982). Two large creek systems interfacing the North Inlet and Winyah Bay systems, South Jones (SJ) and No Mans Friend (NMF) creeks, were extensively sampled by Allen et al. (1982) from August, 1980 through July, 1981. The results of this effort are presented in Table VI.D-4. Eighty-five species of fish were identified. Similarities between this and the Wenner et al., (1981) study of Winyah Bay included the dominance of juvenile fishes at all stations, the importance of relatively few species, and seasonal changes in fish diversity. As would be expected from the high (30-34 $^{o}/oo$) salinity regime of the North Inlet system, several of the typically freshwater stenohaline species sampled in Winyah Bay were absent.

With regards to the North Inlet fish study, Allen et al. (1982) concludes that "NMF and SJ are populated by large numbers of finfishes, most of which are juveniles. The diversity and abundance of fishes, especially during the summer, indicates that these creeks are very important nursery areas for coastal species. Almost all of the species which are of commercial and recreational significance in South Carolina occurred at the creeks. The majority of these species were represented by postlarval or young juveniles which had migrated from remote spawning locations to marsh creek habitats which provided rich food supplies and shelter from larger predators."

Additional fisheries data from the North Inlet estuary can be obtained by review of Cain and Dean, 1976; Shenker and Dean, 1979; and Bozeman and Dean, 1980. Also, the Long Term Ecological Research program in North Inlet has generated more than 3 years of biweekly trawl and seine data from a number of locations in the major creeks of this high salinity estuary. It is the beginning of a data set which will continue for at least 10 years. The purpose of this [illegible] is to establish patterns and causes for seasonal and annual fluctuations in abundance

Table VI.D-4. Taxonomic list of fishes collected with all gear types from August 1980 through July 1981. X indicates presence at No Man's Friend (NMF) and South Jones (SJ) Creeks, in trawls, in gill nets (GN) epibenthic sled or zooplankton nets (SL/PLK). OCC. represents the number of times the species occurred in trawl collections on major cruises at either creek out of a total of 18 samplings (9 at NMF and 9 at SJ).
(Allen et al. 1982)

FAMILY	GENUS-SPECIES	COMMON NAME	NMF	SJ	TRAWL	GN	SL/PLK	OCC.
Carcharhinidae	*Carcharhinus obscurus*	dusky shark	X			X		1
	Rhizoprionodon terraenovae	Atlantic sharpnose shark	X	X		X		4
Sphyrnidae	*Sphyrna lewini*	scalloped hammerhead	X	X		X		2
Dasyatidae	*Dasyatis americana*	southern stingray	X	X		X		4
	Dasyatis centroura	roughtail stingray	X			X		1
	Dasyatis sabina	Atlantic stingray	X	X	X	X		4
Myliobatidae	*Rhinoptera bonasus*	cownose ray	X	X		X		2
Lepisosteidae	*Lepisosteus osseus*	longnose gar	X	X	X	X		5
Elopidae	*Elops saurus*	ladyfish	X	X	X	X	X	4
	Megalops atlantica	tarpon		X			X	0
Anguillidae	*Anguilla rostrata*	American eel		X	X		X	4
Ophichthidae	*Bascanichthys sp.*	whip eel		X	X			1
	Myrophis punctatus	speckled worm eel	X	X			X	0
	Ophichthus gomesi	shrimp eel	X	X	X		?	1
Clupeidae	*Alosa aestivalis*	blueback herring	X	X	X		?	6
	Brevoortia tyrannus	Atlantic menhaden	X	X	X	X	?	14
	Dorosoma cepedianum	gizzard shad		X	X		?	2
	Dorosoma petenense	threadfin shad		X	X		?	1
Engraulidae	*Anchoa hepsetus*	striped anchovy	X	X	X		X	9
	Anchoa mitchilli	bay anchovy	X	X	X		X	17
Synodontidae	*Synodus foetens*	inshore lizardfish	X	X	X		X	7
Ariidae	*Arius felis*	sea catfish	X	X	X	X		7
	Bagre marinus	gafftopsail catfish		X		X		1
Batrachoididae	*Opsanus tau*	oyster toadfish	X	X	X			13
Gobiesocidae	*Gobiesox strumosus*	skilletfish	X	X	X		X	1
Gadidae	*Urophycis floridanus*	southern hake	X	X	X			6
	Urophycis regius	spotted hake	X	X	X			2
Ophidiidae	*Rissola marginata*	striped cusk-eel	X	X	X			6
Cyprinodontidae	*Cyprinodon variegatus*	sheepshead minnow		X	X			1
	Fundulus heteroclitus	mummichog	X	X	X		?	
Atherinidae	*Membras martinica*	rough silverside		X			X	0
	Menidia menidia	Atlantic silverside	X	X	X		X	5
Syngnathidae	*Syngnathus floridae*	dusky pipefish	X	X	X		X	3
	Syngnathus fuscus	northern pipefish	X		X		X	1
	Syngnathus louisianae	chain pipefish	X	X	X		X	3
Serranidae	*Centropristis philadelphica*	rock sea bass	X		X			1
	Mycteroperca microlepis	gag grouper		X	X		X	3
Pomatomidae	*Pomatomus saltatrix*	bluefish	X	X	X	X		7
Rachycentridae	*Rachycentron canadum*	cobia		X	X			1
Carangidae	*Caranx hippos*	crevalle jack	X	X	X	X		5
	Chloroscombrus chrysurus	Atlantic bumper	X	X	X			5
	Selene vomer	lookdown	X	X	X			2
Lutjanidae	*Lutjanus griseus*	gray snapper		X	X		X	1
Gerreidae	*Diapterus olisthostomus*	Irish pompano	X	X	X			2
	Eucinostomus argenteus	spotfin mojarra	X	X	X		?	3
	Eucinostomus jula	silver jenny		X	X		?	1
Pomadasyidae	*Orthopristis chrysoptera*	pigfish	X	X	X		X	2
Sparidae	*Archosargus probatocephalus*	sheepshead	X	X	X		X	5
	Lagodon rhomboides	pinfish	X	X	X		X	11

Table VI.D-4. (Concluded)

FAMILY	GENUS-SPECIES	COMMON NAME	NMF	SJ	TRAWL	GN	SL/PLK	OCC.
Sciaenidae	*Bairdiella chrysoura*	silver perch	X	X	X		X	14
	Cynoscion nebulosus	spotted sea trout	X	X	X	X	X	10
	Cynoscion regalis	weakfish	X	X	X	X	X	1
	Leiostomus xanthurus	spot	X	X	X	X	X	17
	Menticirrhus americanus	southern kingfish		X	X	X	X	2
	Menticirrhus littoralis	gulf kingfish		X		X		1
	Menticirrhus saxatilis	northern kingfish		X	X	X		2
	Micropogonias undulatus	Atlantic croaker	X	X	X	X	X	11
	Pogonias cromis	black drum		X	X			1
	Sciaenops ocellata	red drum	X	X	X		X	3
	Stellifer lanceolatus	star drum	X	X			X	0
Ephippidae	*Chaetodipterus faber*	Atlantic spadefish	X	X	X			5
Mugilidae	*Mugil cephalus*	striped mullet		X	X	X	X	3
	Mugil curema	white mullet	X	X	X			6
Blenniidae	*Hypsoblennius hentzi*	feather blenny	X	X	X		X	3
	Chasmodes bosquianus	striped blenny		X			X	0
Gobiidae	*Gobionellus boleosoma*	darter goby	X	X			X	0
	Gobionellus hastatus	sharptail goby	X	X	X		X	1
	Gobionellus shufeldti	freshwater goby	X	X			X	0
	Gobiosoma bosci	naked goby	X	X	X		X	2
	Gobiosoma ginsburgi	seaboard goby	X	X			X	0
	Microgobius gulosus	clown goby		X			X	0
	Microgobius thalassinus	green goby		X			X	0
Scombridae	*Scomberomorus maculatus*	Spanish mackerel		X	X			1
Stromateidae	*Peprilus alepidotus*	harvestfish		X	X			1
	Peprilus triacanthus	butterfish		X	X			1
Triglidae	*Prionotus tribulus*	bighead searobin	X	X	X		X	4
Bothidae	*Ancylopsetta quadrocellata*	ocellated flounder	X	X	X			5
	Citharichthys spilopterus	bay whiff	X	X	X		X	7
	Etropus crossotus	fringed flounder	X	X	X			12
	Paralichthys dentatus	summer flounder	X	X	X	X	X	4
	Paralichthys lethostigma	southern flounder	X	X	X	X	X	15
Soleidae	*Trinectes maculatus*	hogchoker	X	X	X		X	8
Cynoglossidae	*Symphurus plagiusa*	blackcheek tonguefish	X	X	X		X	17
Balistidae	*Monacanthus hispidus*	planehead filefish		X			X	0
Tetraodontidae	*Sphoeroides maculatus*	northern puffer	X				X	0

of important species of fishes, crabs, and shrimps in an unpolluted estuarine system.

With reference to the Winyah Bay fisheries systems as a whole, Wenner et al. (1981) offer the following characterizations: "The large amount of coastal marshland and freshwater input which characterizes the Winyah Bay system provides physiological suitability, an abundant food supply, and a refuge from predators, criteria which determine ideal estuarine nursery grounds." In summation, there is little doubt from review of the somewhat limited literature of the Winyah Bay fishery that the bay appears significant as a nursery and supports resident populations as well as stenohaline marine species and euryhaline transients which utilize the estuary during a portion of their life cycle.

g. **Anadromous Fish**

Winyah Bay and its tributary rivers provide habitat for anadromous fishes of commercial and recreational importance including American shad (Alosa sapidissima), hickory shad (Alosa mediocris), blueback herring (Alosa aestivalis), Atlantic sturgeon (Acipenser oxyrhynchus) and striped bass (Morone saxatilis) (Leland, 1968; White and Curtis, 1969; Crochet, 1975). In addition, Winyah Bay has been reported as the most important refuge for the endangered shortnose sturgeon in its southern range (see Endangered Species section).

The Winyah Bay system is the principal shad producing area in the state (Ulrich et al., 1980). After an intensive sampling study, Crochet (1975) drew several general conclusions regarding the seasonal migration patterns for the American and hickory shad in Winyah Bay. Juvenile hickory shad descend the rivers in late spring, and by July the major nursery area is in Winyah Bay proper. They remain in Winyah Bay throughout their first summer, then enter the ocean in early fall. American shad utilize the upper Winyah Bay system (river mouths above the Highway 17 bridge) during their first summer, and the bay proper becomes their nursery area in December. They migrate from the bay to the ocean during February. However, this general picture may vary from year to year depending on annual temperature regimes.

South Carolina accounts for 55% of the total U.S. landings for the Atlantic sturgeon, and the Winyah Bay area is the primary fishing ground for this species in South Carolina (Smith et al., in press) (although most of the actual fishing occurs in the ocean adjacent to Winyah Bay). Migratory patterns of the juvenile Atlantic sturgeon in the Winyah Bay system were examined by Smith et al., (1982). Conclusive data on specific seasonal phases of the total life-history pattern are lacking (Ted Smith, S.C. Wildlife and Marine Resources Department, personal communication). Juvenile sturgeon appear to display a seasonal migration within the river-estuary system, inhabiting the lower river system during the warmer months and the higher salinity estuary during colder periods. Data suggests that they leave the lower river regions around early September and arrive in the estuarine bays in November where they remain until mid-June. They appear to move randomly around Winyah Bay, frequently moving to the area around the jetties. Although substantial numbers of juvenile sturgeon can be captured on the mud flats behind the jetties from January-March, it is not known whether these individuals return to the estuary and river with oncoming warmer temperatures, or if they migrate offshore or along the coast.

Smith et al., (1982) also report on the location of an apparent sturgeon nursery area in the lower Waccamaw River extending from Butler Island to 1.2 km upstream, where repeated capture of fingerlings was made.

5. COMMERCIAL FISHERIES VALUES OF WINYAH BAY

The principal commercial fishery resources of the Winyah Bay system include estuarine and marine finfish species, anadromous fishes, shrimp, and blue crab. Commercial landings and ex-vessel value for 1979 through 1982 are shown in Table VI.D-5. Annual, reported ex-vessel commercial landing values averaged close to $1.5 million over this time period. However, this figure is conservative because some landings do not pass through normal market channels and thus are not recorded in landing statistics.

Over 400 professional fishermen on approximately 200 fishing vessels are stationed in the Winyah Bay vicinity (1980 data, Fishery Information Management Section, NMFS). Eleven full time and three part time fish dealers in the vicinity also depend largely on the catch of bay-dependent species for their livelihood.

Marine and estuarine finfish species in the commercial catch include southern kingfish, spot, flounder, grouper, king mackerel, red porgy, black sea bass, and vermillion snapper, although some of these species are not estuarine dependent. Commercial gill nets set in Mud Bay yield large numbers of mullet, red drum, spotted seatrout, menhaden which are sold for crab bait, young Atlantic and shortnose sturgeon, and incidental catches of small adult striped bass. When salinities are depressed by high river discharges, yellow bullheads and gars are also caught (Allen et al., 1982).

Although not reflected in local commercial landing statistics, sizeable quantities of Atlantic menhaden are harvested in nearshore waters by purse seiners who unload their catch at fish meal plants in North Carolina and Florida. Southern kingfish, spot, and flounder are harvested by shrimp trawlers as an incidental catch while trawling for shrimp, and catch statistics do not accurately reflect abundance of these species. The commercial catch of grouper, snapper, porgy, and black sea bass is harvested by handline snapper-grouper vessels, bottom longline vessels and trap fishermen from offshore live bottom areas. This offshore catch is not included in the above landings values, but would increase them appreciably if added.

The commercial anadromous fishery includes Atlantic sturgeon, American shad, and hickory shad. The ex-vessel value of the anadromous fishery was over $198,000 in 1982 (Table VI.D-5). Winyah Bay is the principal shad and sturgeon-producing area in the state. The gill-net fishery for American shad extends from the nearshore ocean waters of the bay mouth, many miles upstream in the Waccamaw, Pee Dee, and Black rivers. Early in the run, there is an intensive gill net fishery along the surf zone extending from Murrell's Inlet to the Santee Delta. Heaviest fishing effort is concentrated in the Waccamaw River from U.S. Highway 17 to Bull Creek, in the Pee Dee from Bull Creek to the mouth of the Little Pee Dee River, and in the Black River upstream to Andrews (Ulrich et al., 1980). The commercial season for shad occurs during the annual spawning migration from January to May.

The Atlantic sturgeon fishery is concentrated in the ocean near the harbor jetties where set gill nets are the principal gear employed. The economic value

Table VI.D-5. Commercial seafood landings in Winyah Bay and adjacent waters, 1978-1982 (John Devane, Fishery Information Management Section, National Marine Fisheries Service).

	1978		1979		1980		1981		1982	
	lbs.	Value ($)	lbs.	Value ($)	lbs.	Value ($)	lbs.	Value ($)	lbs.	Value ($)
Winyah Bay										
Shad	4,200	2,896	48,900	45,121	ND	ND	69,062	41,279	ND	ND
Sturgeon	94,200	31,422*	22,900	12,087*	ND	ND	ND	ND	ND	ND
Blue crab	170,100	42,949	158,800	41,711	224,862	62,444	207,621	61,395	77,934	34,214
Shrimp	11,900	26,546	23,900	59,320	31,242	41,726	5,373	13,166	152,258	428,031
Other fish & shellfish	13,800	18,769	11,500	23,738	8,281	13,976	11,766	3,097	3,539	2,700
TOTAL	294,200	121,882	266,000	181,977	264,385	118,146	293,462	118,937	233,731	464,945
Waccamaw River										
Shad	45,500	31,147	41,200	36,773	50,228	42,135	108,280	67,638	15,998	13,426
Blue crab	139,100	32,429	115,600	24,867	151,380	35,689	155,081	39,174	16,529	6,777
TOTAL	184,600	63,576	156,800	61,640	201,608	77,824	263,361	106,812	32,527	20,203
Pee Dee River										
Shad	107,100	79,465	13,500	8.950	7,363	5,657	6,615	1,086	12,311	8,923
Blue crab	ND	ND	ND	ND	127,016	27,031	ND	ND	ND	ND
Menhaden	ND	ND	ND	ND	ND	ND	357	54	ND	ND
TOTAL	107,100	79,465	13,500	8,950	134,389	32,688	64,181	37,347	12,311	8,923
Black River										
Shad	1,400	691	16,100	11,103	9,266	7,549	19,479	14,427	5,685	4,561
Blue crab	ND	ND	ND	ND	ND	ND	400	180	ND	ND
TOTAL	1,400	691	16,100	11,103	9,266	7,549	19,879	14,607	5,685	4,561
Ocean Waters (Inshore Georgetown Co.)										
Whiting	1,000	150	2,200	433	3,620	984	1,588	311	12,517	3,649
Flounder	700	268	2,400	851	8,109	3,284	5,618	2,217	9,370	5,451
Spot	100	13	3,100	606	3,282	959	ND	ND	18,930	3,505
Shrimp	497,100	871,516	743,900	211,267	997,083	1,826,183	271,091	554,949	601,818	1,551,590
Shad	ND	ND	8,900	5,991	80	80	141,869	81,707	80,303	65,783
Sturgeon	ND	ND	56,400	35,283*	130,805	92,124*	91,973	52,626*	100,153	77,482*+
Sheepshead	ND	ND	100	25	ND	ND	ND	ND	ND	ND
Other fish	ND	ND	ND	ND	2,425	759	ND	ND	ND	ND
TOTAL	498,900	871,947	817,000	254,456	1,145,404	1,924,373	512,139	691,810	823,041	1,707,460

ND - No data available.

* - Does not include the value of roe (caviar) which greatly exceeds the value of the flesh (Smith et al, in press).

+ - Statewide (although Winyah Bay sturgeon fishery accounts for 90% of statewide catch (Smith et al, in press).

of this fishery has been substantially underestimated because until recently caviar has not been included in the valuation. Smith et al. (in press) demonstrates a greater than doubling of sturgeon fishery values by including roe valuation.

Since 1900, North Carolina and South Carolina fishermen have accounted for most of the Atlantic sturgeon landings. In 1976, their combined production comprised 84% of the total landings from Maine to Louisiana (NMFS, 1980). The Winyah Bay sturgeon fishery produces about 90% of the total fish landed in South Carolina (Smith et al., in press).

The commercial shrimp fishery in the Winyah Bay/Cape Romain area accounts for approximately 10% of the total landings and value for shrimp in South Carolina. Shrimp species harvested include white, brown, and pink shrimp, but white shrimp are by far the most important species in terms of dollar value both in Winyah Bay and in South Carolina waters as a whole. Total value of the shrimp fishery in the Winyah Bay area was close to $2 million during the 1982 season (Table VI.D-5). The shrimp fishery consists of a channel net and trawl fishery in lower Winyah Bay and a trawl fishery in nearshore ocean waters particularly near the entrance channel.

The blue crab fishery is relatively minor in dollar value with approximately twenty commercial crabbers landing the majority of the catch. The 1982 value of the crab fishery was slightly over $40,000 (Table VI.D-5).

Future Commercial Fishery Enterprises - During 1977, a fishery for young American eels (elvers) was initiated in lower Winyah Bay. This fishing effort took place primarily in the vicinity of Belle Isle Gardens and Esterville Plantation during January through March. Although the value of the catch only amounted to $10,000, the potential for growth of this fishery, and for adult eels as well, appears to be excellent in this estuary.

Aquaculture in existing impoundments in and around the Winyah Bay system for species such as shrimp, blue crabs and crayfish represents another potential future source of commercial fisheries enterprise. One aspect of a large S.C. Sea Grant Consortium-sponsored impoundment study in the adjacent Santee River system is to refine management techniques towards the commercial feasibility of such a venture. A series of impoundments adjacent to the Atlantic Intracoastal Waterway (AIWW), approximately one mile south of its confluence with Winyah Bay are currently being prepared for the aquaculture of crayfish.

6. RECREATIONAL FISHERIES OF THE WINYAH BAY SYSTEM

Recreational fisheries in the Winyah Bay vicinity include surf fishing, bridge fishing, general inshore small boat fishing, offshore trolling, offshore bottom fishing, party boat fishing, shrimping, and crabbing. Recreational fishing activity is heaviest near the harbor jetties for species such as red drum, bluefish, flounder, seatrout, tarpon, and sheepshead. Striped bass are caught by recreational fishermen in the upper bay and lower reaches of the tributary rivers. Common species of recreational finfish are shown in Table VI.D-6.

Recreational fishing pressure in Winyah Bay is low in comparison to other major estuaries in the State. However, the bay probably has the highest growth rate of recreational fishing use in the State (Don Hammond, S.C. Wildlife and Marine Resources Department, personal communication). Although any comprehensive

Table VI.D-6. Common recreational finfish caught in coastal South Carolina waters (Bearden 1969).

Inshore Species	Offshore Pelagic Species	Offshore Demersal Species
Spotted seatrout	Spanish mackerel	Black sea bass
Black drum	King mackerel	Snapper
Kingfish	Dolphin	Porgy
Red drum	Shark	Grunt
Spot	Bluefish	Grouper
Striped bass	Jack	
Sheepshead	Wahoo	
Atlantic croaker	Tuna	
Pigfish	Barracuda	
Flounder	Cobia	
Silver perch	Sailfish	
Tarpon	Marlin	
Pompano		
Cobia		
Bluefish		
Spadefish		
Shark		

surveys of recreational fishing in the Winyah Bay system are not available, past surveys of fishing activity in coastal South Carolina provide insight into general levels of participation (Table VI.D-7). Bearden (1969) estimated that in 1968 there were 240,500 resident saltwater anglers (age 12 and over) in South Carolina. A regional survey of the southeastern United States conducted by the National Marine Fisheries Service (Mabrey et al., 1977) estimated that 396,000 South Carolina residents participated in marine recreational finfishing during 1974. This represents a 10.8% annual increase in anglers between 1968 and 1974. Cupka (S.C. Wildlife and Marine Resources Department, personal communication) estimated an overall economic impact of $117 million for South Carolina saltwater angling, excluding non-resident participation. The 1973 and 1974 NMFS regional surveys (Ridgely and Deuel, 1975; Mabrey et al., 1977) estimated that a total of 685,000 non-residents participated in marine recreational fishing in South Carolina during the study years. Although the dollar value of marine recreational fisheries cannot be estimated for Winyah Bay, it is likely that this fishery represents an important asset to the local economy.

7. ECOLOGY OF THE SAMPIT RIVER

a. Wetlands

Wetlands associated with the Sampit River include tidal freshwater marshes and impoundments, brackish marshes, and forested wetlands. Brackish marshes dominated by big cordgrass surround the mouth and lower reaches of the river. Extensive freshwater marshes dominate the middle reaches of the river, but a fringe marsh of big cordgrass may extend as far up as river Mile 7 and along major creek banks with strong tidal influence. Above river Mile 9 to its headwaters near Sampit, South Carolina, the Sampit River is bordered by a narrow floodplain of swamp forest dominated by bald cypress-water tupelo associations. This community is also found surrounding the headwaters and upper reaches of the major creeks feeding the Sampit River. For a more extensive description of the above communities refer to the Wetlands Section of this document.

b. Phytoplankton and Benthic Algae

Very little information exists regarding phytoplankton, and virtually no information exists with regard to benthic algae, for the Sampit River. Based solely on similarities in salinity regime, one may speculate that phytoplankton assemblages in the mid to lower Sampit River may be similar in nature to those of upper Winyah Bay. Standing stock and productivity of phytoplankton are anticipated to be lower within segments of the Sampit influenced by the discharge plume from International Paper (EAF, 1982). These differences are due to increases in light attenuation from turbidity and color associated with the plume. Chlorophyll "a" samples from a Sampit River station were taken as part of the second year sampling effort of a two-year study done by Belle W. Baruch Institute for Marine Biology and Coastal Research. Should analysis of this data, when completed, reveal significant new information, it will be included in the final EIS.

c. Zooplankton

Limited zooplankton sampling was reported in Allen et al. (1982). From this information, portions of the Sampit appear to accommodate zooplankton

Table VI.D-7. Resident participation in various segments of the South Carolina marina recreational fisheries.

Segment	Number of Resident Participants	Number of Fishing Days	Year Survey Was Conducted	Survey Source
Surf and bank fishing	41,600	--	1968	Bearden (1969)
Small boat fishing	121,000	--	1968	Bearden (1969)
Pier fishing	30,000[a]	200,000	1968	Bearden (1969)
Pier fishing	25,000[a]	228,000	1974	Hammond and Cupka (1977)
Offshore trawling	26,000	--	1968	Bearden (1969)
Offshore bottom fishing	20,000	--	1968	Bearden (1969)
Total finfishing	174,000	--	1968	Bearden (1969)
Total offshore private boat fishing	14,305[b]	225,981[c]	1973	Bromberg (1973)
Total inshore private boat fishing	19,507[b]	339,885[c]	1973	Bromberg (1973)
Recreational shrimping	16,780	115,117	1974	S.C. Marine Resources Division, Charleston, unpubl. data
Total finfishing	396,000	2,572,000	1974	U.S. Dept. of Commerce, NOAA (1977b)
Total shellfishing	283,000	1,117,000	1974	U.S. Dept. of Commerce, NOAA (1977b)
Private boats - artificial reef fishing	3,947[d]	33,550[e]	1977	Liao and Cupka (1979)
Private boats - offshore (non-artificial reef fishing)	3,526[d]	93,549[e]	1977	Liao and Cupka (1979)

a. Number includes residents and nonresidents.
b. In terms of number of boats.
c. In terms of number of boat days.
d. In terms of number of boats measuring over 16 ft. (4.9 m) in length.
e. In terms of number of boat days, boats measuring over 16 ft. (4.9 m) in length.

assemblages similar to the upper Winyah Bay, reaching highest total abundances in the summer months. Dominant species included two copepods Acartia tonsa and Acartia copepodids, gastropod veligers, barnacle nauplii and crab zoea (primarily fiddler and mud crabs). However, the data presented in Allen et al. (1982) was compiled from a single Sampit River station relatively near the mouth. As such, it can not be interpreted as representative of the river. An additional station upriver near Pennyroyal Creek was added to the second year of sampling by the Belle W. Baruch Institute for Marine Biology and Coastal Research.

d. Benthic Organisms

1. Benthic infauna

Detailed infaunal sampling by both hand-held corer and ponar grab was done in the Sampit River from May, 1980 through July, 1981 by EAF (1982). They found considerable seasonal variation in the distribution of individual populations and patterns of numerical abundance. A cluster analysis of the data indicated three major faunal groupings by area: upper to mid-Sampit River, mid to lower Sampit River and upper Winyah Bay. These groupings may occur as a result of salinity differences and/or organic and pollutant discharges associated with the International Paper (IP) effluent. Dominant infaunal species in the Sampit River all are species normally associated with high concentrations of organic matter and include the oligochaete worms Tubicificoides heterochaetus, the polychaete worms Boccardia ligerica and Hypaniola florida and the amphipod Corophium lacustre. Species diversity (eveness component) was lowest in the portions of the Sampit River most affected by the IP effluent, and both diversity and relative abundance increased with distance from the effluent.

2. Benthic epifauna

Results of epifaunal sampling in the Sampit River appear in EAF (1982) and Allen et al. (1982). The EAF sampling site was located in the lower Sampit near the IP discharge, and the Allen et al. sampling site was near the river's mouth.

Palaemoneid shrimp comprised the bulk of the catch in the vicinity of the IP outfall. Other species present included blue crabs, mud crabs, and white and brown shrimp. However, this station had low numbers of species and low relative abundance compared to other sections of Winyah Bay, which led EAF to the conclusion that "observed changes in water quality, due to the discharge of mill effluent, appeared to affect the distribution of epibenthic invertebrates in the Sampit River relative to other areas in Winyah Bay."

Mysid shrimp dominated the samples at the Sampit River mouth, and gammarid amphipods represented the next most dominant group. Other epibenthic assemblages, including the fish larvae, were similar to those sampled at other upper bay and river stations (refer to epifaunal section of Winyah Bay).

Since both of the above sample sites were restricted to the lower Sampit River, neither of these studies are representative of mid and upper portions of the Sampit. Preliminary observations from unpublished data collected by extensive sampling by the Belle W. Baruch Institute for Marine Biology and Coastal Research during 1981-1982 at a station near Pennyroyal Creek (mid Sampit River -

vicinity Mile 5) indicate somewhat low epibenthic densities not significantly different from other river and upper Winyah Bay stations.

The highest densities of fish larvae occurred in March and May. Fish larvae in the epibenthic catch were dominated by spot but also included croaker, silver perch, red drum, black drum, star drum, hogchoker, tonguefish, southern flounder, weakfish and spotted seatrout. Other notable components of the epibenthic catch included crab larvae, decapod shrimp, amphipods and mysids, all important food items for higher trophic level fish.

e. Shellfish

There does not appear to be a significant molluscan shellfish (clam and oyster) resource in the Sampit River. The occurrence of blue crabs, and white and brown shrimp collected in epibenthic, otter trawl, and marsh seine sampling (EAF, 1982; Allen et al., 1982) indicates that the Sampit River may provide habitat and nursery areas for these species.

f. Finfish

Finfish sampling in the lower Sampit River was done by EAF (1982) and Wenner et al. (1981). A qualitative list of fishes from EAF otter trawls and marsh seine sampling appears in Table VI.D-8. Over the entire sampling period, EAF's station in the vicinity of the IP outfall was characterized by a relatively depauperate fauna when compared to other sections of the bay, indicating an adverse effect on the fish fauna in receiving portions of the Sampit River relative to other areas of Winyah Bay. In a somewhat contrasted finding, Wenner et al. reported that "The Sampit River supported a richer fauna than the other distributaries entering Winyah Bay. This higher diversity may be related to the higher overall salinity of the Sampit River." They also reported a predominance of freshwater species, transients and catadromous and anadromous species.

g. Recreational and Commercial Fisheries

Recreational fishing in the Sampit River is primarily centered around freshwater species, such as largemouth bass and bluegill (Jack Whetstone, Sea Grant, personal communication). There is even an annual largemouth bass tournament in the upper Sampit River. Recreational opportunities for saltwater angling and cast netting for shrimp and fish also exist in mid to lower river segments.

No direct commercial fishing harvest is done in the Sampit River. However, in as much as the Sampit River provides nursery habitat for commercially valuable species, it indirectly supports commercial fishing interests.

h. Summary - Sampit River Aquatic System

The paucity of data available for the Sampit River makes it difficult to perform an accurate characterization of the aquatic biological system. Studies to date have concentrated on the lower end of the river which is characterized by polluted disturbances from industry and periodic dredging (see earlier water quality section). Data from a sampling station at Pennyroyal Creek (Sampit River - approximately Mile 5) may provide additional insight into the mid-river

Table VI.D-8. Qualitative list of fishes sampled in the Sampit River 1980-1981 (compiled from EAF, 1982).

Otter Trawl Sampled Species:	
Anchoa mitchilli	Bay anchovy
Anquilla rostrata	American eel
Bairdiella chrysura	Silver perch
Brevoortia tyrannus	Atlantic menhaden
Citharichthys spilopterus	Bay whiff
Cynoseion regalis	Weakfish
Gobionellus shufeldti	Freshwater goby
Ietalurus catus	White catfish
Leiostomus xanthurus	Spot
Micropogonias undulatus	Atlantic croaker
Morone sp.	Bass
Myrophis punctatus	Speckled worm eel
Paralichthys lethostigma	Southern flounder
Paralichthys sp.	Flounder
Stellifer lanceolatus	Star drum
Symphurus plagiusa	Blackcheek tonguefish
Trinectes maculatus	Hogchoker
Marsh Creek Seine Sampled Species:	
Menidia beryllina	Tidewater silverside
Gambusia affinis	Mosquitofish
Brevoortia tyranus	Atlantic menhaden
Fundulus confluentus	Marsh killifish
Fundulus majalis	Striped killifish
Paralichthys lethostigma	Summer flounder
Mugil cephalus	Striped mullet
Gobionellus shufeldti	Freshwater goby

segment which is further removed from pollution sources. This data was collected during the second year of the Belle W. Baruch Institute for Marine Biology and Coastal Research's two-year study of Winyah Bay. Preliminary observations from this data indicate that the lower and mid-river portions of the Sampit may function as more of a brackish nursery area than the other Winyah Bay tributaries. Recruitment may be somewhat affected by poor flushing and long residence time for water exchanged with Winyah Bay. However, it is this physical phenomena which permits entrapment of saline waters, perpetuating the brackish nursery role.

Absolutely no data is available for upper freshwater segments of the Sampit River, where the majority of recreational use takes place. The transition from brackish to freshwater systems occurring in the vicinity of river Mile 7, will be accompanied by a change in the biological components of the system. These components are likely to respond differently and have different tolerances to hydrocarbon inputs.

8. ENDANGERED SPECIES

A number of threatened and/or endangered species occur in the vicinity of Winyah Bay. Table VI.D-9 contains a list of the species that were considered during the consultation process that took place in accordance with Section 7 of the Endangered Species Act for the CRDC refinery project. No critical habitat for any of the species listed in Table 9 has been identified by the U.S. Fish and Wildlife Service or the National Marine Fisheries Service in the project area. However, there are several endangered species recovery plans being considered for approval which would officially designate critical habitat areas in the Winyah Bay region. Critical habitat means the specific areas essential to the conservation of the species.

Of the species listed in Table VI.D-9, a discussion of those well documented to occur in the project area and most likely to be affected by the project, follows.

a. American alligator - Alligator mississippiensis

Alligators inhabit the river systems, canals, lakes, swamps, bayous, and marshes of the coastal plain from northeastern North Carolina southward to Florida and along the Gulf coast to Texas. They occur in the Mississippi drainage north to Arkansas and southeastern Oklahoma. In the late 1950's and early 1960's alligator populations reached all-time lows from excessive exploitation. The combination of hunting and illegal poaching for the commercially valuable hides resulted in severe declines throughout most of the species range. Habitat losses from human encroachment and drainage of wetlands have also been factors in the decline. During recent years, most alligator populations have responded to legal protection by increasing steadily. The Louisiana population has increased to the point where it has been removed from the Federal list of endangered and threatened species and a limited hunting season is now permitted.

Populations in South Carolina are estimated roughly at 48,000 individuals. The area around Winyah Bay, including marshes adjacent to the proposed refinery site, reportedly supports the densest nesting population of alligators in the northern part of the state. Their principal habitat in these areas consists of

Table VI.D-9. Threatened (T) and endangered (E) species considered in the Section 7 consultation for the CRDC refinery project.

Species	Status	Responsible Federal Agency
Florida manatee (Trichechus manatus)	E	FWS
Arctic peregrine falcon (Falcoperegrinus tundrius)	E	FWS
American alligator (Alligator mississippiensis)	E,T	FWS
Brown pelican (Pelecanus occidentalis)	E	FWS
Bald eagle (Haliaeetus leucocephalus)	E	FWS
Red-cockaded woodpecker (Picoides borealis)	E	FWS
Loggerhead sea turtle (Caretta caretta)	T	FWS, NMFS
Kemp's ridley turtle (Lepidochelys kempii)	E	FWS, NMFS
Green turtle (Chelonia mydas)	T	FWS, NMFS
Hawksbill turtle (Eretomochelys imbricata)	E	FWS, NMFS
Leatherback turtle (Dermochelys coriacea)	E	FWS, NMFS
Humpback whale (Megaptera novaeangliae)	E	NMFS
Finback whale (Balaenoptera physalus)	E	NMFS
Sei whale (Balaenoptera borealis)	E	NMFS
Right whale (Eubalaena glacialis)	E	NMFS
Sperm whale (Physeter catadon)	E	NMFS
Blue whale (Baelenoptera musculus)	E	NMFS
Shortnose sturgeon (Acipenser brevirostrum)	E	NMFS

old ricefield impoundments, which are now managed mainly for wintering waterfowl. Alligators are particularly abundant on South and Cat islands within the Yawkey Wildlife Center.

b. Atlantic Loggerhead Sea Turtle - Caretta caretta

The loggerhead is a species with worldwide distribution in temperate and subtropical waters. Major nesting beaches are in eastern Australia, southeastern Africa, and the southeastern United States. Nesting in the U.S. occurs on suitable beaches from North Carolina through Florida and to a lesser extent on barrier beaches of the Gulf coast. The majority of the most heavily used nesting beaches in the U.S. are on the east coast of Florida. In South Carolina, the nesting season runs from mid May to early September.

Major factors influencing the decline of this species include loss of suitable nesting habitat resulting from human encroachment on beaches (this includes the problem of hatchling disorientation arising from presence of artificial lights); excessive predation of the nests by raccoons, ghost crabs, foxes, and humans; and accidental drowning of adult turtles when they become trapped in gill nets and shrimp trawls.

Over 50 % of South Carolina's loggerhead nesting occurs on the islands from Winyah Bay to Cape Island (Cape Romain National Wildlife Refuge). The barrier island beaches near the mouth of Winyah Bay provide one of the State's principal nesting areas. North Island has approximately 100 nests per season; Sand Island has about 250 nests per season, and South Island has about 150 nests per season. Other adjacent islands and smaller side beaches of Sand and South islands, which front on Winyah Bay, are also utilized for nesting, resulting in a total of approximately 650 nests per summer on the beaches in the vicinity of the proposed project. Loggerheads also feed in the waters of Winyah Bay and have been found in adjacent creeks.

c. Eastern Brown Pelican - Pelecanus occidentalis

The brown pelican ranges along the Atlantic coast from North Carolina south to Florida and around the Gulf Coast to Texas. Populations occur outside the United States on the Gulf Coast of Mexico, the West Indies, Caribbean Islands, and to Guyana and Venezuela in South America. Nesting in the southeastern United States is confined to the Carolinas, Florida, and Louisiana.

The major factor influencing the decline of the brown pelican appears to have been persistent pesticide residues biomagnified in the food chain. The principle compounds include DDT and its metabolites DDE and DDD, polychlorinated biphenyls, dieldrin, and endrin. Concentrations of these residues in the tissues of brown pelicans have caused mortality in adults and failure of reproductive mechanisms, including production of eggs with extremely thin shells which could not be incubated without being crushed. Other detrimental factors include human disturbance of nesting colonies and mortalities resulting when birds are caught on fish hooks and become entangled in monofilament line. Pelicans are an extremely sensitive indicator of environmental contamination by persistent chlorinated hydrocarbons. In a matter of approximately four to six years the Louisiana population of 70,000 was eliminated as a result of these chemical pollutants. The Texas population has also been drastically reduced. The South Carolina population was reduced during the decade of the 1960's from

an estimated 5,000 breeding pairs to approximately 1,250 (Blus, 1970). Today there are approximately 3,200 breeding pairs of brown pelicans in South Carolina. Because of the favorable response of pelicans after the banning of the use of persistent pesticides such as DDT, many populations of this species appear to be making good progress toward recovery. Those along the East Coast and in Florida appear to have stabilized at this time, prompting a recommendation from the Brown Pelican Recovery Team for removal or downlisting of the pelican from the endangered species list in the area from North Carolina to Mississippi. The U.S. Fish and Wildlife Service is currently reviewing this recommendation as a possible basis for future reclassification of the species.

Even though South Carolina populations do not appear to have suffered quite as drastically as those in Louisiana and parts of Texas, significant declines in eggshell thickness and weight have been documented (Blus, 1970). In relatively recent studies, eggs were taken from South Carolina, Florida, and Texas and analyzed for residues of numerous environmental contaminants. The South Carolina eggs had the lowest concentrations of mercury and similarly, very low levels of lead in all the eggs sampled. Nevertheless, South Carolina was shown to have the thinnest-shelled pelican eggs in the southeast (Blus et al, 1974).

There are presently two areas utilized by pelicans as rookeries in South Carolina. These are islands in the mouth of the Stono River south of Charleston; and Marsh and Bird islands, which are part of the Cape Romain National Wildlife Refuge located just south of the mouth of Winyah Bay.

Brown pelicans are known to utilize the islands at the mouth of Winyah Bay, including Cedar, South, and North islands, for loafing. Although pelicans utilize Winyah Bay for feeding, it is not heavily used because of the swift and muddy nature of the water in the bay (Phil Wilkinson, S.C. Wildlife and Marine Resources Department, personal communication). Pelicans are visual feeders which fly over the surface of the water looking for fish and then dive from the air to make their catch. Apparently areas with persistently turbid waters, such as Winyah Bay, are not used as feeding areas as much as areas with clear water because the pelicans have difficulty seeing their prey. However, dozens of pelicans can be observed fishing with large flocks of terns on the large populations of mullet and menhaden in Mud Bay, especially during the warm months (Dennis Allen, Baruch Institute, personal communication).

d. **Bald Eagle - *Haliaeetus leucocephalus***

The bald eagle is found throughout the United States and northward to the Arctic. Nesting in the Southeast is limited principally to peninsular Florida and, to a much lesser extent, the coastal areas of Louisiana, Mississippi, and South Carolina. The birds occur elsewhere in the Southeast primarily as migrants. This species is basically riparian, usually nesting near expanses of open water where they feed. Bald eagles are opportunistic feeders and will take a variety of vertebrate species as prey, both living and carrion. Fish appear to be a preferred food item and constitute the major part of the diet when abundant. In South Carolina, nesting occurs in late winter, with the usual clutch consisting of two eggs. A second clutch may be laid if the first is lost. Young require four to five years to reach breeding age.

Bald eagle populations and reproductive success have declined significantly in many areas of the United States in the last 20 years (Wiemeyer et al., 1972). High residue levels of chlorinated pesticides, particularly dieldrin, have

resulted in egg shell thinning and mortality of adults. The most frequent single cause of mortality, however, was found to be illegal shooting (Mulhern et al., 1970). Along with pesticide residues, heavy metals have also been found concentrated in eggs and carcasses and blamed for mortality (Wiemeyer et al., 1972).

In the southeastern United States, outside of Florida, substantial nesting populations of bald eagles occur only in the states of Louisiana and South Carolina. One third of South Carolina's nesting eagles reside in the Winyah Bay area (five pairs). Biologists believe the South Carolina eagles are reproducing at levels which barely allow this species to hold its own here (Tom Murphy, S.C. Wildlife and Marine Resources Department, personal communication). Due to the location of the five active eagle territories, it is possible that the adults from the three nearest territories fish in Winyah Bay. Concentrations of subadult birds, involving as many as ten birds at a time, are regularly seen in winter, feeding in a western channel of the bay near Esterville Plantation. At one time or another, all of the subadults from South Carolina nests may feed in this area.

e. Shortnose Sturgeon - Acipenser brevirostrum

Shortnose sturgeon populations range from the St. John River, New Brunswick, Canada, to the St. John's River, Florida. They occur in rivers, estuaries and the sea within a few miles of land, but reach their greatest abundance in estuaries fed by major rivers. These fish are anadromous, moving up the river systems during spring to spawn. Shortnose sturgeon are not known to move between river systems. Therefore, each river may contain separate stocks. Three geographical regions can be noted. A northern distribution area is found between the St. John River in New Brunswick, Canada to the Merrimack River in Massachusetts, a central area includes the Connecticut River Hudson River, and Delaware River, and a southern area can be described between Cape Hatteras and the St. John's River, Florida, although the species is believed to be extirpated in North Carolina. The status of shortnose sturgeon in Winyah Bay is poorly understood. No quantitative population estimates are available for the Winyah Bay population (National Marine Fisheries Service, 1982).

However, Table VI.D-10 shows the number of shortnose sturgeon that have been found in their southern area of distribution. From this table, it can be seen that more shortnose sturgeon have been found in Winyah Bay than in all other areas of the South combined. The fact that the shortnose catch in Winyah Bay was incidental (Marchette, unpublished manuscript), as compared to directed capture efforts in areas like the Altamaha River, is also notable.

From this incidental catch data it appears that a very substantial and significant population of the shortnose sturgeon utilize Winyah Bay and its major tributary rivers, with the area behind Butler Island and similar areas on the Black and Pee Dee rivers serving as summer sanctuaries, and the channel area and flats of Muddy Bay serving as over-wintering sanctuaries (Marchette, unpublished manuscript) (see Figure VI.D-3). In their October, 1982 letter to Colonel Stalmann of the Charleston District Corps of Engineers, the National Marine Fisheries Service interpreted this data to indicate that "The Winyah Bay system may be the most important refuge for shortnose sturgeon in its southern range."

Table VI.D-10. Numbers of shortnose sturgeon found in their southern area of distribution.

Locality	Date	Number of Fish
Charleston, S.C.	1896	1
South Santee River, S.C.	1978	3
South Edisto River, S.C.	1978-1979	3
Atlantic Ocean, S.C.	1982	2
Pee Dee River, S.C.	1982	3
Winyah Bay, S.C.	1978-1982	138
Charleston Harbor, S.C.	1978	1
Lake Marion, S.C.	1979	11
Savannah River, GA	1975-1980	4
Lower Ogechee River, GA	1973	1
Altamaha River, GA	1974-1979	43
Ocumulgee River, GA	1978	3
Big Lake George, FL	1949	1
Lake Crescent, FL	1949	1
Murphy Creek, FL	1977	1
Welaka, FL	1978	1
Cedar Creek, FL	1979	1
Clay/Putnam Co. Line, FL	1979	1

From: Dadswell, M. J., B. D. Taubert, T. S. Squiers, D. Marchette, and J. Buckley. Unpublished Manuscript. Synopsis of biological data on shortnose sturgeon, Acipenser brevirostrum LeSueur 1818. 118 p.

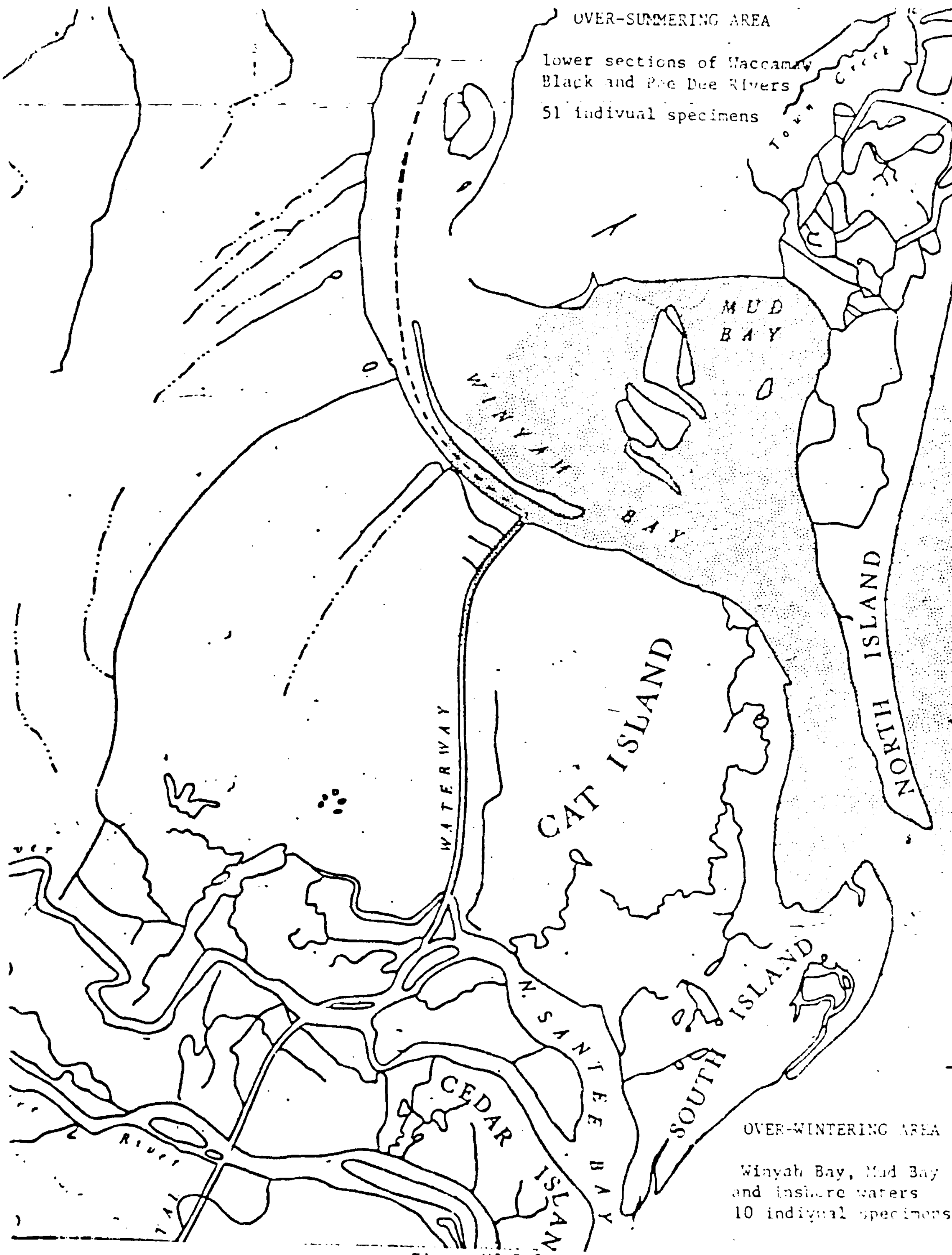


Figure VI.D-3
Over-wintering and over-summering areas for shortnose sturgeon in Winyah Bay (Marchette, unpublished manuscript)

9. SPECIES OF SPECIAL EMPHASIS

Species of Special Emphasis (SSE) have been designated by the U.S. Fish and Wildlife Service (FWS) based upon FWS legal responsibilities and/or management concerns. Selected species encompass those determined to be of the highest interest and key indicators of recognized major problems. Several biological, political, economic and social criteria were considered in species selection. Emphasis is on migratory birds, threatened and endangered species and anadromous fish.

Eighteen species designated as Regional SSE occur in the Winyah Bay area, fifteen of which are also designated as National SSE (see Table VI.D-11). Of the eighteen Regional SSE, fifteen are aquatic or wetland oriented species.

Table VI.D-11. Regional Species of Special Emphasis in the Winyah Bay Area.

Birds	
American woodcock*	Scolopax minor
Bald eagle*	Haliaeetus leucocephalus
Black duck*	Anas rubripes
Canvasback*	Aythya valisineria
Clapper rail	Rallus longirostris
Eastern brown pelican*	Pelecanus occidentalis
Least tern*	Sterna albifrons antillarum
Mallard*	Anas platyrhyncos
Mourning dove*	Zenaida macroura
Osprey*	Pandion haliaetus
Peregrine falcon*	Falco peregrinus anatum
Red-cockaded woodpecker*	Picoides borealis
Redhead duck*	Aythya americana
Wood duck*	Aix sponsa
Fish	
Atlantic sturgeon	Acipenser oxyrhynchus
Striped bass*	Morone saxatilis
Reptiles	
American alligator*	Alligator mississippiensis
Loggerhead sea turtle	Caretta caretta

* Denotes National Species of Special Emphasis.

VI.

F. Socio-Economics

1. Land Use Plans

a. General. The evaluation of existing and future socio-economic conditions in the Georgetown area is based on land-use plans, demographic conditions, economic base conditions, waterborne commerce, tourism and recreation, public services, and education levels. The land-use plan for Georgetown County was part of a three-county regional land-use plan, prepared by a regional planning agency in 1976. The larger nine-county BEA trade region is also used for the discussion of demographic and other associated economic and social factors since additional products for Georgetown Waterborne commerce originate from this larger trade area.

b. Existing Land Use Plans. In 1976 the Waccamaw Regional Planning and Development Council prepared the Waccamaw Regional Land-Use Plan. The objective of the Plan was to provide guidelines for orderly growth and future use of undeveloped land. A land-use plan is designed to provide basic data on factors that affect land uses, land characteristics, the way land is currently being used, and an analysis of these factors to serve as a framework for future land development.

The Waccamaw Regional Land Use Plan utilizes five land-use categories: residential, commercial, industrial, public or semi-public, agricultural or undeveloped. The nature of existing land use in the Waccamaw Region is shown in Table VI. F-1. The three counties of the region are Georgetown, Horry, and Williamsburg Counties.

TABLE VI. F-1

EXISTING LAND USE WACCAMAW REGION[1/]

Land Use Category	Number of Acres	Percent of Total Land
Residential	32,100	1.73
Commercial	773	0.04
Industrial	4,147	0.22
Public	7,595	0.41
Farm/Undeveloped	1,779,748	95.86
Incorporated Places	32,277	1.74
Total Land	1,856,640	100.00

[1/] Pamphlet: Waccamaw Regional Planning and Development Council, Land Use Planning in the Waccamaw Region, A summary of the Comprehensive Plan, 1982.

The Plan recommends a wide variety of residential areas to be separated from incompatible land uses such as industrial or high-intensity commercial. Prime agricultural and forest lands should be protected from conversion to other land uses. The general development goals include:

(1) Efficiency in the use of land.
(2) Greater conservation of energy.
(3) Encourage urban development in areas designated for sewage facilities pursuant to Section 201 of P.L. 92-500.
(4) Protect beaches and riparian resources.
(5) Provide flood protection.
(6) Protect and expand the State Ports Authority facility in Georgetown.
(7) Protect and aid the Myrtle Beach Jetport.
(8) Protect prime industrial waterfront areas.
(9) Provide adequate sites for future business, educational, and recreational facilities.
(10) An efficient transportation within the planning area.
(11) Provide the necessary acreage for projected land-use needs.

A 1983 report prepared by Davis and Floyd, Inc. and Arthur D. Little, Inc. entitled "Georgetown Port and Industrial Development Study"[1] designated industrial sites within Georgetown County. The primary factors which influenced the selection of sites in the county area are as follows:

(1) Land Use/Zoning - The majority of the selected sites are within areas which are proposed for industrial development or are projected to be utilized by industry in existing land-use plans. The majority of the sites are located in the Sampit River - Pennyroyal Road area. (Figure VI. F-1 to Figure VI. F-5).

(2) Acreage - The acreages of the selected sites are diverse enough to reasonably accommodate representatives of most industrial categories.

(3) Location - Sites have generally been located in or near areas of existing industrial development. Proximity to major highways and existing port facilities had substantial impact on site selection. Other factors evaluated were proximity to a railroad spur, water and sewer and power source.

(4) Availability - Many of the sites designated have been previously developed as industrial sites and, generally, all owners appeared to be amenable to selling land for industrial development.

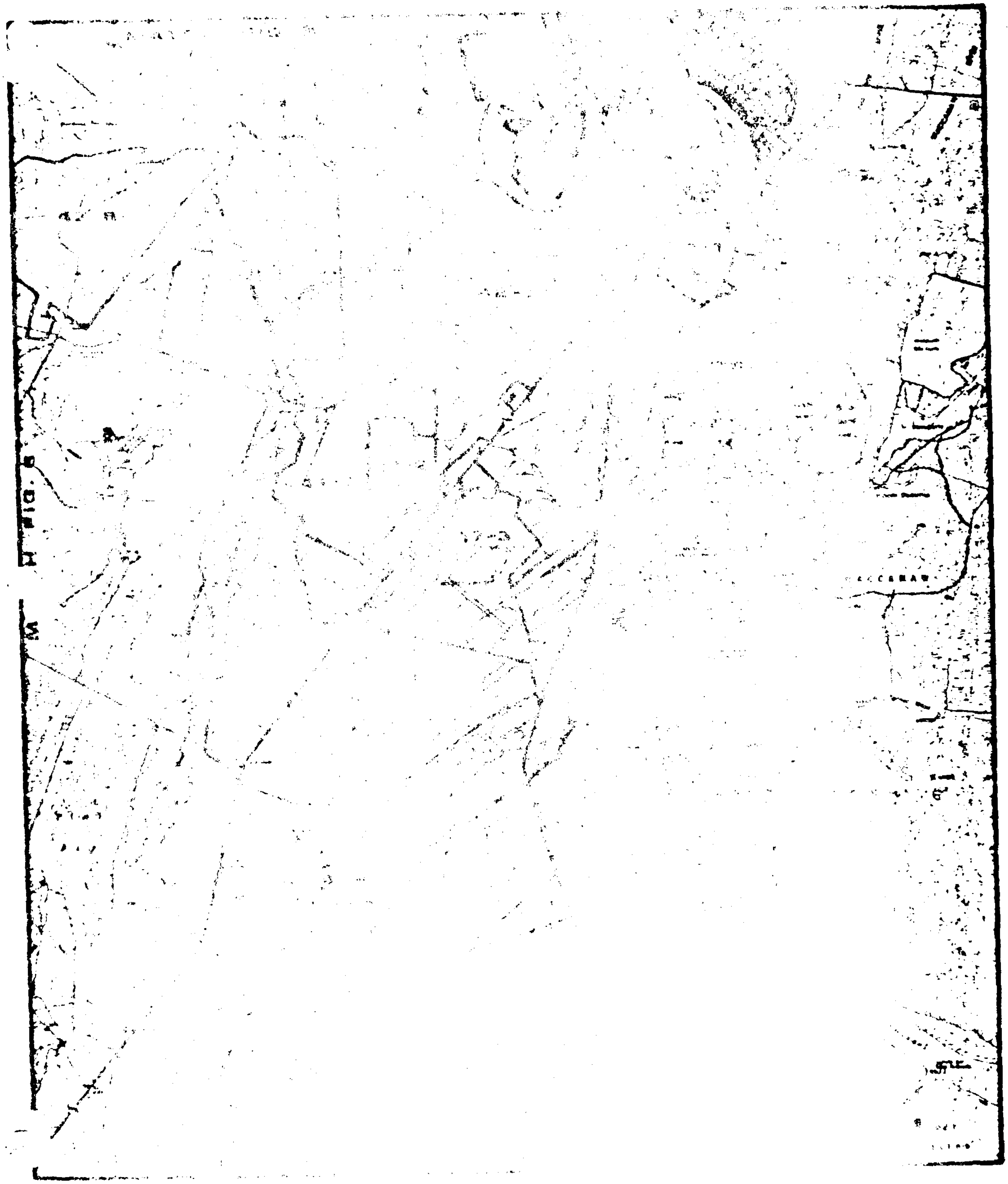
The characteristics of the sites as a group, including the distance to the port, distance to U. S. Highway 17 and the zoning classification are summarized in Table VI F-2.

2. Community Structure

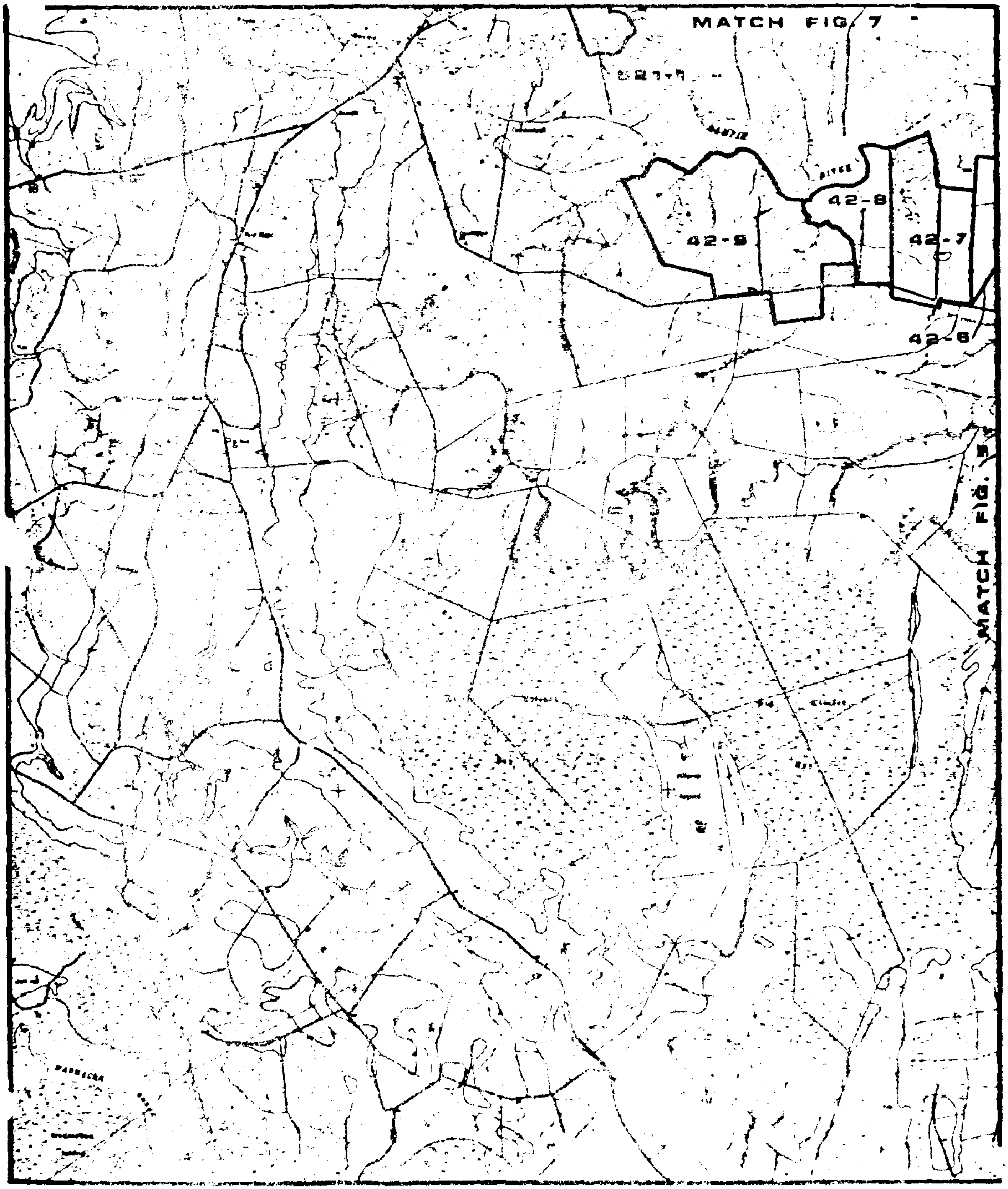
a. Governmental Organization. General purpose units of local government in Georgetown County include the County of Georgetown, the City of Georgetown and the Town of Andrews.

The City of Georgetown is organized with the Mayor/Council form of government. There is a mayor plus six City Councilmen. A City Administrator is responsible for administrative affairs.

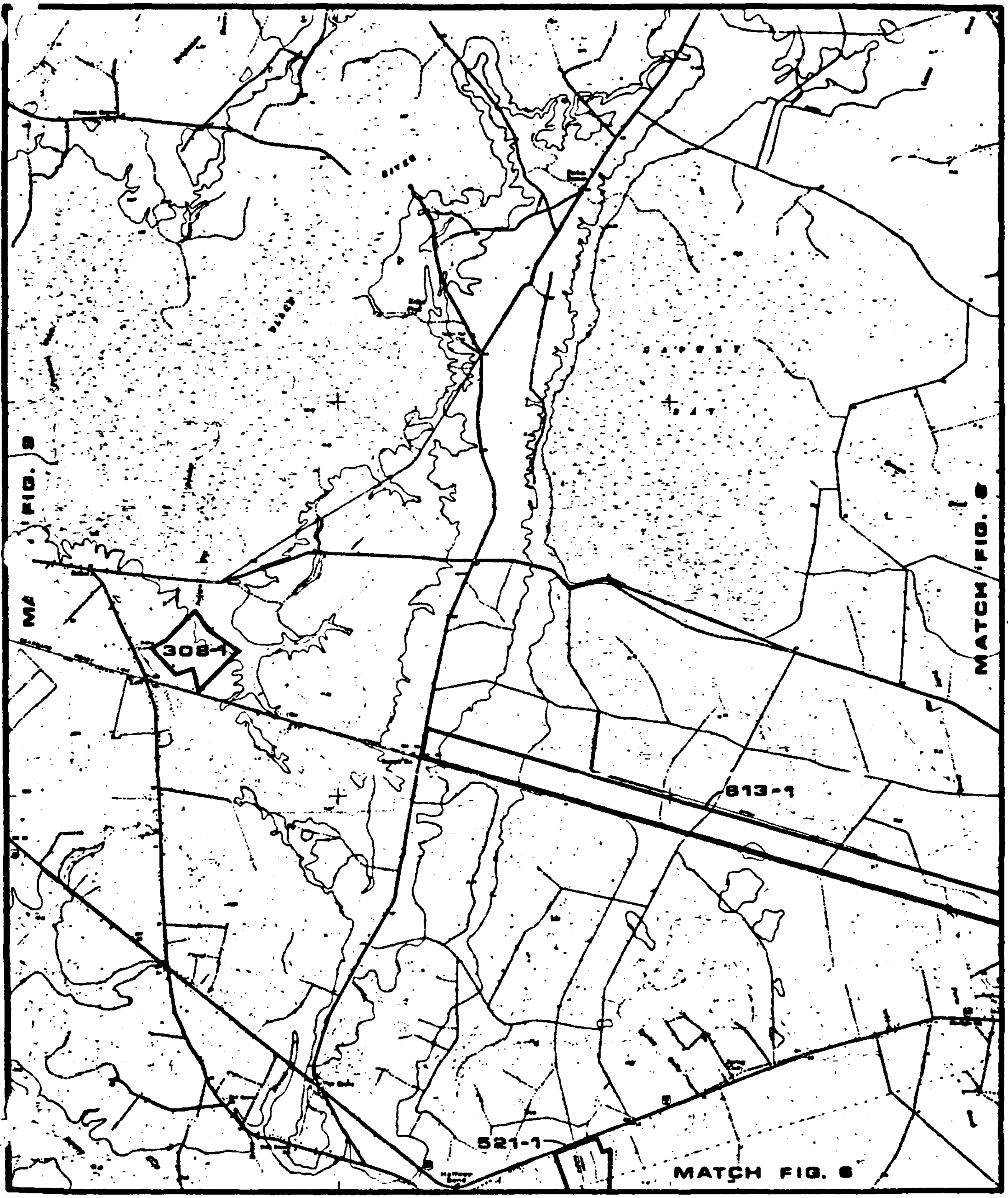
[1]Davis and Floyd, Inc., Arthur D. Little, Inc., Phase II, Appendix D, Site Analysis and Development Costs Georgetown Port and Industrial Development Study, South Carolina State Ports Authority, June 1983.



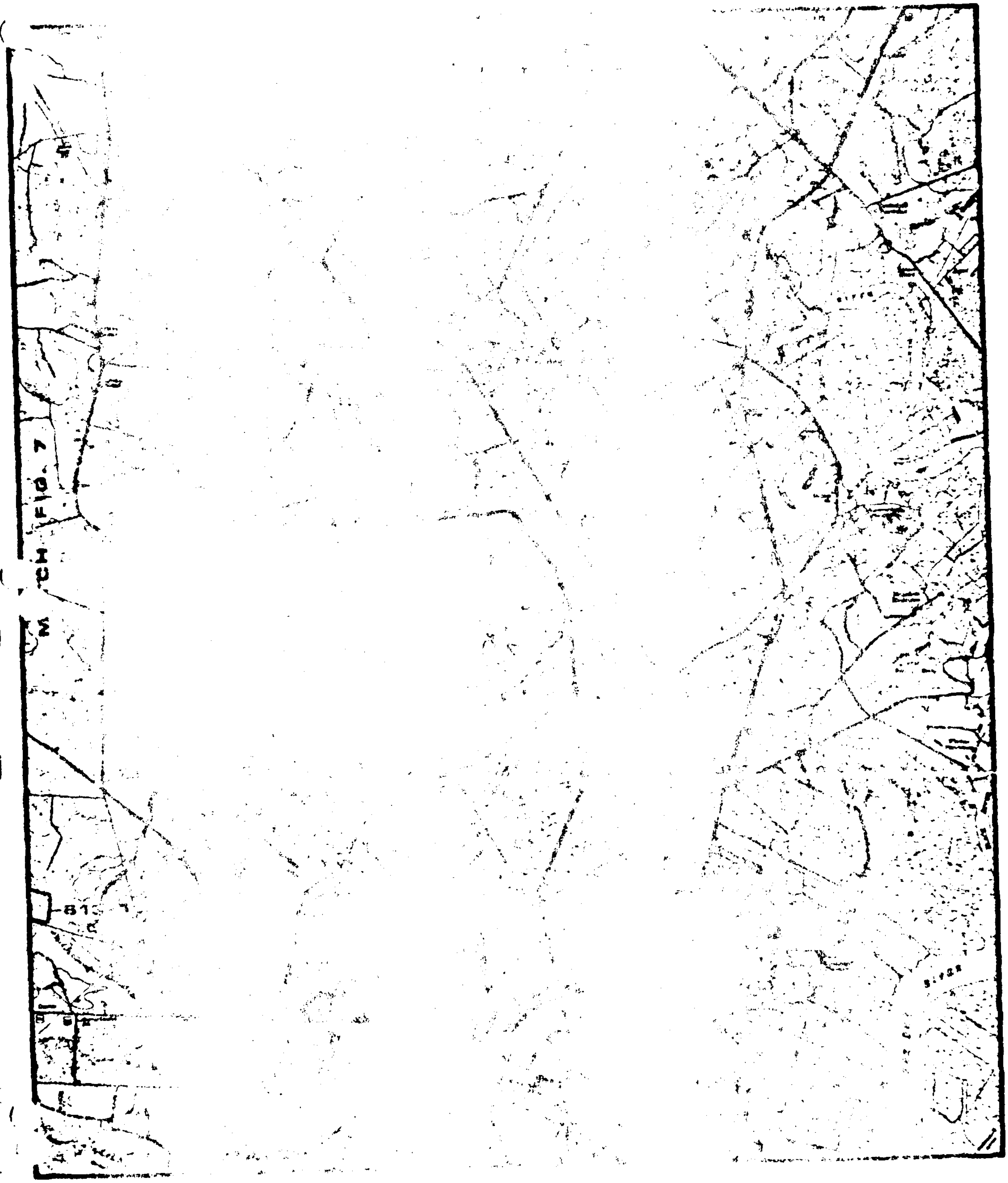
SCALE



DESIGNATED INDUSTRIAL SITES - FIGURE VI. F-2



DESIGNATED INDUSTRIAL SITES – FIGURE VI. F-3



F-4

SCALE : 1 O" = 4848'

DESIGNATED INDUSTRIAL SITES — FIGURE VI.F-6

SUMMARY OF SITE CHARACTERISTICS

USABLE AREA (Acres)		
(2)*	< 50	20-1**, 86-1
(6)	50-100	17-1, 42-2, 42-3, 42-5, 521-1, 308-1
(7)	100-500	17-2, 17-3, 42-4, 42-7, 42-8, 613-1, 20-2
(3)	500-1,000	42-1, 42-6, 42-9

DISTANCE TO EXISTING PORT (Miles)		
(5)	1-5	17-1, 17-2, 17-3, 42-1, 42-3
(7)	5-10	42-2, 42-4, 42-5, 42-6, 42-7, 42-8, 42-9
(2)	10-5	613-1, 521-1
(4)	15-20	308-1, 20-1, 20-2, 86-1

DISTANCE TO HIGHWAY NO. 17 (Miles)		
(4)	0-1	17-1, 17-2, 17-3, 42-1
(4)	1-5	42-2, 42-3, 42-4, 42-5
(4)	5-10	42-6, 42-7, 42-8, 42-9
(3)	10-15	613-1, 521-1, 308-1
(3)	15-20	20-1, 20-2, 86-1

ACCESS BY RIVER BARGE	
YES	NO
17-1, 42-1, 42-2, 42-4, 42-5, 42-6, 42-7, 42-8, 42-9, 521-1	17-2, 17-3, 42-3, 613-1, 308-1, 20-1, 20-2, 86-1
(10)	(8)

LAND COST ($)***		
(15)	< 2,000	17-2, 17-3, 42-1, 42-2, 42-3, 42-4, 42-5, 42-6, 42-7, 42-8, 42-9, 613-1, 521-1, 308-1, 20-2
(1)	2,000-4,000	17-1
(2)	4,000-6,000	20-1, 86-1

ZONING	
INDUSTRIAL	UNCLASSIFIED
17-1, 17-3, 42-1, 42-2, 42-4, 42-5, 42-6, 42-7, 613-1, 20-1, 20-2, 86-1	42-8, 17-2, 42-3, 42-9, 521-1, 308-1
(12)	(6)

* Total Number in Category
** Specific Site Number
*** Estimated Market Value Based on Tax Records

TABLE VI. F-2

The Town of Andrews also has the Mayor/Council form of government with a mayor plus six Town Council members.

b. Law Enforcement. Law enforcement services are provided in the County by the Georgetown County Sheriff's Department and the Police Departments of Georgetown and Andrews. In addition, there is one resident agent of the South Carolina Law Enforcement Division in the County.

The County Sheriff's Department is staffed by the Sheriff and 17 deputies and assisted by an auxiliary force. The Georgetown Police Department has 36 full time officers and 11 auxiliary officers. The Town of Andrews employs 8 full time officers and also has an auxiliary force.

c. Fire Protection. Fire protection is provided by the City of Georgetown, the Town of Andrews, the Midway Fire District serving the Pawley's Island to North Litchfield Beach area, and the Murrell's Inlet Fire District.

The City of Georgetown Fire Department is staffed by 25 paid firemen and 17 volunteer firemen. The Department operates two fire stations and maintains a class 5 fire insurance rating.

The Town of Andrews Fire Department is staffed by one paid fireman and 24 volunteer firemen. The Department operates one fire station and maintains a class 7 fire insurance rating.

The Midway Fire District is staffed by two paid firemen and 44 volunteer firemen. The District operates one station and maintains a class 7 fire insurance rating.

The Murrell's Inlet Fire District is staffed by 31 volunteer firemen, operates one station, and maintains a class 8 fire insurance rating.

d. Higher Education. Six colleges or universities are located within reasonable commuting distance of Georgetown. These include:

Baptist College, Charleston
The Citadel, Charleston
The College of Charleston, Charleston
Francis Marion College, Florence
The Medical University of South Carolina, Charleston
The University of South Carolina, Coastal Carolina Campus, Conway

e. Technical and Vocational Education. The S.C. State Board for Technical and Comprehensive Education has established a technical education system in the state which is considered a model on the national and international level. Horry-Georgetown Technical College, with campuses in Georgetown and Conway provides technical education in the immediate area. In addition to these campuses, there are three more technical colleges within one hour's driving time of Georgetown, including Trident Technical College in Charleston, Williamsburg Technical College in Kingstree, and Florence-Darlington Technical College in Florence.

A system of area vocational schools at the secondary level also serves the state. In addition to the vocational high school in Georgetown, there are nine other vocational schools within one hour's driving time of Georgetown, which prepare graduates for the local employment market.

f. Local Public and Private Schools. Other than the vocational high school mentioned above, there are 18 local public schools in the county. These schools offer education at the kindergarten-elementary level, the junior high or middle school level and the high school level, with several offering more than one level. Fourteen schools provide kindergarten-elementary education, six provide middle or junior high level, and four are high schools.

There are seven private or church sponsored schools. Six offer kindergarten-elementary education, four provide middle schoo or junior high level, and two include high school.[2]

[2] Community Profile of Georgetown, S.C., Wilbur Smith & Associates, 1981.

3. Public Services

a. Water. The City of Georgetown provides water to residents, industries and businesses in and around Georgetown. Treatment is by a six million gallon per day (gpd) treatment plant which utilizes an up-flow clarifier, sand and anthracite filters, pre- and post-chlorination and a post-treatment corrosion inhibitor. Peak consumption is approximately 2.25 mgd. This system could be expanded to 12 mgd with minimal effort and expense, and was designed to be ultimately expanded to 24 mgd. Raw water is drawn from the Pee Dee River through a 27-mile canal with an existing capacity of eight million gallons per day and is also obtained from four deep wells. The raw water supply could be increased with additional pumping capacity.

The city of Andrews receives its water from five wells with a combined pumping capacity of 2.5 mgd. It is estimated that the average daily demand exceeds 1.2 mgd. Water treatment is by chlorination only.

The Georgetown County Water and Sewer District operates several water and sewer systems and provides service to residents and businesses in rural areas north and west of the City of Georgetown. The water and sewer system consists of eleven wells, an elevated tank and distribution lines. Average static and residual pressure in the several systems are estimated to be 60-65 pounds per square inch (psi) and 50 psi, respectively. The following table is a list of the District's eleven wells and their pumping capacities:

WELLS	PUMPING CAPACITY
Red Hill	110 gpm
Rose Hill	108 gpm
Plantersville	95 gpm
Murrells Inlet	245 gpm
North Pawleys Island	170 gpm
Pennyroyal	100 gpm est.
Hagley	80 gpm est.
North Litchfield	200 gpm
South Litchfield	200 gpm
West Highway 17	200 gpm
Sampit	174 gpm est.

There are no industrial customers currently being served by the Water and Sewer District and no industrial rate schedule is in existence.

Raw water (surface and ground water) for process and cooling is abundant throughout Georgetown, Horry and Williamsburg Counties.[3]

b. Sewage. The City of Georgetown's sewage collection and treatment system consists of a gravity-line network serving approximately 3,500 customers. There are 13 pumping stations which pump effluent into an oxidation pond for chlorination treatment. Presently, the treatment system's capacity is 2 mgd, and its capacity is currently under review to upgrade the facility to accommodate the demands of a 20-year growth period.

The sewerage system serving the City of Andrews consists of collector and trunk lines, lift stations, and three faculative stabilization ponds covering approximately 17 acres. The design capacity of the system is 653,000 gpd, although due to substantial infiltration problems, current use is approximately 1.2 mgd. Presently, a wastewater management program is underway to correct deficiencies.

[3]Community Profile of Georgetown, S.C., Wilbur Smith & Associates, 1981.

The Georgetown County Water and Sewer District operates three separate sewage collection and treatment facilities and serves residential and business customers located in rural areas north and west of the City of Georgetown. At present, 486 residential and 5 large commercial users (Waccamaw School, Old Litchfield Inn, New Litchfield Inn, Litchfield Motel Laundry, and St. Andrews Association Shopping Center) are tapped onto the system.

The District's system serving Pawleys Island has a design capacity of 50,00 gpd and serves an estimate 20,000 gpd demand. This facility contains grit removal, mechanical aeration, secondary sedimentation, sand filter and chlorination systems. In addition, the Hagley and Wedgefield sewage systems are package plants with design capacities of 50,000 and 30,000 gpd, respectively. These two facilities, at present, are estimated to be operating at 1/3 of capacity. There are no industrial customers tapped onto these systems; no pretreatment requirements are in place, and no industrial rate schedules have been developed.

c. Electric Power. Electric power supply is provided by Santee-Cooper (South Carolina Public Service Authority) and by Carolina Power and Light Company (CP&L). Electric power distribution is accomplished by the two suppliers.

Santee-Cooper is an electric utility owned by the State of South Carolina. Approximately 2,800 miles of its transmission lines are in Georgetown County. Santee Cooper has recently completed construction of a major generating facility in Georgetown County off Pennyroyal Road south of the City of Georgetown.

Retail customers are served directly by the utility in Litchfield Beach and Pawley's Island. Also the utility sells power to the Santee Electric Cooperative for distribution to its customers located west of the Pee Dee River and Winyah Bay. In addition, the City of Georgetown purchases power from Santee-Cooper and retails it to customers within the City Limits.

Carolina Power and Light Company is an investor-owned utility operating in South Carolina under regulation of the South Carolina Public Service Commission. The company provides electric service to and around the city of Andrews. Presently, CP&L has a generating capacity of 7,400 megawatts, and its construction program provides for additional generating units to be added at intervals into the 1990's. Projection of load growth and generation resources reveal sufficient reserves to accommodate industrial expansion throughout the company's South Carolina service area.

d. Natural Gas. The South Carolina Electric and Gas Company provides natural gas service to customers in Georgetown County. The distribution line serving the County extends northeastward from an area near Ladson in Berkeley County to an area north of the Santee River and just south of Little Kilsock Bay. From this area, the line branches with one pipeline serving the City of Andrews and another serving the City of Georgetown.

e. Fuel Oil. Georgetown County is served by oil jobbers which make fuel oil available to residential, commercial and industrial customers in the County. There are six member firms of the S. C. Oil Jobbers Association in the City of Georgetown, and one in Andrews. In addition, the [illegible] Hess Corporation receives bulk petroleum products through the Port of Georgetown for storage and distribution from a bulk storage facility adjacent to the Port, from which it supplies local industrial customers.

4. Tourism and Recreation

a. Parks. Huntington Beach is a popular state park, located south of Murrells Inlet on the Atlantic Ocean. Total attendance was [illegible],840 in 1981. Beach use and camping are the principal recreation uses of the 2500 acre state park. Other Georgetown County state parks are the [illegible] Game

TABLE VI. F-3

TOURISM BUSINESS IN
THE GRAND STRAND
(Horry County and Georgetown County)

	1980	1981	INCREASE
TOURISM-TRAVEL EXPENDITURES:			
Horry County	$777,548,000	$875,960,000	
Georgetown County	31,219,000	33,967,000	
TOTAL EXPENDITURES	$808,767,000	$909,927,000	13%
TOURISM-GENERATED PAYROLL			
Horry County	$148,324,000	$167,589,000	
Georgetown County	5,721,000	6,224,000	
TOTAL PAYROLL	$154,045,000	$173,813,000	13%
TOURISM-GENERATED JOBS:			
Horry County	25,572	26,676	
Georgetown County	955	956	
TOTAL JOBS	26,527	27,632	4%
STATE TAXES COLLECTED:			
Horry County	$ 36,902,000	$ 42,277,000	
Georgetown County	1,350,000	1,479,000	
TOTAL STATE TAXES	$ 38,252,00	$ 43,756,00	14%
LOCAL TAXES COLLECTED:			
Horry County	$ 4,600,000	$ 5,202,000	
Georgetown County	131,000	142,000	
TOTAL LOCAL TAXES	$ 4,731,000	$ 5,344,000	13%

The $909,927,000 in 1981 tourism expenditures in the Grand Strand was 38% of the total $2.36 billion in tourism expenditures within all 46 counties of South Carolina.

Source of Information:

Compiled by South Carolina Department of Parks, Recreation and Tourism from U.S. Travel Data Center's 1981 and 1980 Travel-Tourism Reports on South Carolina.

TABLE VI. F-4

POPULATION CHANGE, GEORGETOWN COUNTY, 1960-1980

Georgetown County Census Divisions	1960[1/]	1970[2/]	1980[3/]	Percent Change 1960-1980
Andrews Division	5,482	5,174	6,914	26.2
Gerogetown Division	16,685	15,638	19,281	15.5
Plantersville Division	3,102	2,499	2,706	-12.7
Pleasant Hill-Folly Grove Division	3,339	3,059	3,518	7.2
Sampit Santee Division	3,576	3,977	3,519	- 1.6
Waccamaw Division	2,614	3,153	6,523	149.5
Total	34,798	33,500	42,461	22.0
Georgetown County Urban Areas				
Andrews (Part)[3/]	2,940	2,831	3,034	3.2
Georgetown City	12,261	10,449	10,144	-17.3
Murrell's Inlet[4/]	NA	NA	2,410	-

[1/] U.S. Department of Commerce, Bureau of the Census, United States Census of Population 1960, South Carolina, Number of Inhabitants.

[2/] U.S. Department of Commerce, Bureau of the Census, 1980 Census of Population and Housing, South Carolina, Final Population and Housing Unit Counts, Advance Reports, March 1981.

[3/] The population of the part of Andrews located in Williamsburg County was 55 persons, 48 persons, and 95 persons in 1960, 1970 and 1980, respectively.

[4/] Murrell's Inlet is a census designated place. The datum was obtained from the South Carolina Statistical Abstract, 1982, a publication of the South Carolina Division of Research and Statistical Services.

Management Area and the Santee Delta Game Management Area. Public hunting for waterfowl is the principal recreation use on these game management areas.

Georgetown County had 23 county parks in 1979. In addition, the City of Georgetown had 4 city parks. None of the parks are near the proposed oil refinery site.

b. Boats. Boat registration in Georgetown County increased from 1,124 persons in 1960 to 4,[illegible] in 1981, and increase of 3,704 boats or 330 percent. In 1979, 26 boat landings and 14 commercial boat facilities were located in Georgetown County. The City of Georgetown had one boat landing and five commercial boat facilities.

c. Tourism-Travel. In 1981, the tourism-travel expenditures of 33.9 million dollars in Georgetown County represented only 3.7 percent of the 909.9 million dollars for the total Grand Strand area (Table VI. F-3). The tourism-travel expenditures for adjacent Horry County was 875.9 million dollars in 1981. All of the coastline of Horry County southward to Pawley's Island, in Georgetown County, represents the Grand Strand area.

5. Economic Base and Income

a. Population. The total population of the nine counties located in BEA Economic Area 033 was 490,043 in 1980. This population represented a 22 percent increase since 1970. The Georgetown County population was 42,461 in 1980, an increase of about 26 percent since 1970. Both the total population of the BEA Economic Area 033 and Georgetown County had somewhat greater percentage increases in population between 1970 and 1980 than the total population for the state of South Carolina which had about a 20 percent increase. The average increase for the total United States population was only about 11 percent during the last decade. The population growth rates experienced during the past decade are expected to decrease during the 1980-2000 year projection period.

Georgetown County experienced a population decline between 1960 and 1970 (Table VI. F-5). The Georgetown census division also declined between 1960 and 1970, but increased during the 1970-1980 decade. Population in the City of Georgetown declined between 1960 and 1980, indicating the growth in population has occured outside the city limits of Georgetown, mainly in the adjacent Georgetown, Andrews and Sampit Santee census divisions.

b. Income. Historical and projected personal income, labor and proprietors income, by place of residence and by place of work for BEA Economic Area 033 are shown in Table VI. F-5. Total personal income, by place of residence, was projected to increase from about 1.69 billion dollars in 1978 in 1972 dollars, to about 9.43 billion dollars by the year 2030, an increase of over 450 percent. Total personal income in Georgetown County was projected to increase by approximately the same percentage between the years 1978 to 2030 (Table VI. F-6).

In 1979 per capital income for the City of Georgetown was $5,703, and median household income was $12,367. The average per capita income for the 18 communities was $5,[illegible] and the average median household income was $12,920. In 19[illegible] the per capita income for the State of South Carolina was $6,657 and the average for the United States was $8,773.

c. Housing. The number of occupied housing units in Georgetown County increased from [illegible] units in 1960 to 1[illegible],333 units in 1980, an increase of 68.1 percent. Owner-occupied [illegible] increased [illegible] percent during the same period. In 1960 the median value of homes was $[illegible], but increased to $36,000 in 1980. Median rent increased from $[illegible] in 19[illegible] to $[illegible] in 1980, an increase of 140 percent.

TABLE VI. F-5

PERSONAL INCOME, AND LABOR AND PROPRIETORS INCOME 1969 and 1978, AND PROJECTED 1985-2030 1/

BEA ECONOMIC AREA 033: FLORENCE, SC

PERSONAL INCOME	HISTORICAL		PROJECTED			
	1969	1978	1985	1995	2010	2020
BY PLACE OF RESIDENCE						
Total Personal Income	1,036,519	1,690,852	2,315,764	2,868,157	4,095,797	9,437,490
BY PLCE OF WORK						
Total Labor and Proprietors Income	849,136	1,294,147	1,761,867	2,169,427	3,068,132	6,710,648
Agricultural Production	86,130	82,021	83,502	84,805	88,897	121,532
Nonfarm	763,006	1,212,125	1,678,365	2,084,622	2,979,234	6,589,116
Private	655,881	1,034,880	1,456,776	1,823,983	2,631,900	5,889,778
Agricultrual Services, Forestry, Fisheries & Other	3,550	9,708	12,880	15,138	19,726	38,421
Mining	1,531	2,250	3,544	4,402	6,552	13,381
Construction	43,839	68,076	88,936	107,453	145,201	300,751
Manufacturing	290,452	451,433	640,823	802,378	1,145,012	2,517,595
Nondurable goods	198,383	267,423	348,988	418,458	565,606	1,164,308
Durable goods	92,069	184,011	291,836	383,920	579,406	1,353,287
Transportation and Public Utilities	42,748	71,493	97,513	121,633	176,622	401,422
Wholesale Trade	31,720	57,315	81,538	100,673	146,100	322,025
Retail Trade	100,676	146,615	197,993	241,813	339,238	727,249
Finance, Insurance, and Real Estate	26,312	45,524	67,826	87,033	130,783	307,673
Services	115,053	182,465	265,722	343,461	522,666	1,261,262
Government	107,125	177,245	221,589	260,639	347,334	699,338
Federal Civilian	15,549	21,436	26,852	31,871	43,011	86,482
Federal Military	20,878	27,768	32,259	36,199	44,154	82,013
State and Local	70,698	128,041	162,478	192,570	260,169	530,843

1/ This data was obtained from the 1980 OBERS, BEA REGIONAL PROJECTIONS, Vol. 8, Region 5 Southeast, July 1981, U. S. Department of Commerce, Bureau of Economic Analysis.

TABLE VI. F-6

TOTAL PERSONAL INCOME, POPULATION, PER CAPITA INCOME, & EARNINGS BY INDUSTRY - SELECTED YEARS 1969-2040
(T.P.I. AND EARNINGS IN THOUSANDS OF 1972$; PER CAPITA INCOME IN 1972$), GEORGETOWN COUNTY 1/

	1969	1978	1985	1990	1995	2000	2010	2020	2030	2040
TOTAL PERSONAL INCOME	77,661	143,027	192,771	239,448	285,578	342,411	472,789	617,666	798,779	1,032,998
PER CAPITA INCOME	2,354	3,594	4,307	5,013	5,704	6,507	8,152	9,829	12,054	14,782
PER CAPITA RELATIVE (U.S. = 100)	57	69	68	70	72	74	75	77	78	79
TOTAL EARNINGS	63,396	110,808	149,740	185,123	219,051	262,378	357,467	457,106	581,126	739,031
Agric. Production	1,923	2,073	2,247	2,275	2,330	2,378	2,597	2,880	3,248	3,663
Agr. SVS., F.,+ F.	256	4,343	5,472	6,186	6,881	7,816	9,963	12,176	15,057	18,620
Mining	0	(D)2/	(D)	(D)	(D)	(D)	(D)	(D)	(D)	(D)
Construction	1,600	4,935	7,993	10,234	12,156	14,448	19,323	24,180	30,359	38,117
Total Manufacturing	31,933	54,768	72,393	89,899	106,221	127,429	174,138	224,432	286,067	364,703
Nondurable Goods	25,154	29,851	35,490	41,279	47,160	54,469	71,904	90,352	113,155	141,713
Durable Goods	6,779	24,917	36,903	48,620	59,061	72,960	102,234	134,080	172,912	222,990
Transp., Comm.,+ P.U.	1,573	3,158	4,475	5,657	6,812	8,303	11,524	14,820	18,937	24,198
Wholesale Trade	1,132	(D)2/	(D)	(D)	(D)	(D)	(D)	(D)	(D)	(D)
Retail Trade	6,923	10,479	14,399	17,649	20,910	24,824	33,460	42,214	53,261	67,199
Finance, Ins.,+ R.E.	1,443	2,895	4,991	6,675	8,303	10,347	14,688	19,084	24,593	31,697
Services	8,816	12,320	17,492	22,388	27,417	33,817	48,082	62,778	81,400	105,546
Total Government	7,797	13,159	16,428	19,368	22,258	26,010	34,101	42,357	52,818	65,863
Federal Civilian	460	962	1,185	1,409	1,627	1,905	2,495	3,089	3,833	4,756
Federal Military	519	515	576	647	710	780	970	1,190	1,465	1,804
State & Local	6,818	11,682	14,667	17,312	19,921	23,316	30,636	38,078	47,520	59,303

1/ Department of Commerce, Bureau of Economic Analysis, Regional Economic Analysis Division, County-Level Projections of Economic Activity and Population, South Carolina, 1985-2040.

2/ (D) not shown to avoid disclosure of confidential information, data are included in higher level totals.

In 1980 the City of Georgetown had 3,820 year round housing units, averaging 2.81 persons per household. The median value of specified owner housing was $35,600. By comparison, the median value for Town of Andrews was only $28,600 while the resort and commercial fishing town of Murrell's Inlet was $51,600.

d. Industrial. In 1982 about 522 firms were reported operating in manufacturing, mining and public utilities within the BEA Economic Area 033. Fifty-seven firms were reported operating in Georgetown County. The total capital invested through 1982 was 1.87 billion dollars and the total 1982 value of products manufactured was 4.23 billion dollars. About 56,555 persons were employed in these industries in 1982, and these persons earned total wages of 759.1 million dollars. About 588.1 million dollars have been invested in Georgetown County, about 31 percent of the total capital invested in the nine county BEA Economic Area.

e. Seafood Landings. In 1981 the value of whole fish in Georgetown County was about 1.67 million dollars, or approximately 41 percent of the total value of the commercial seafood fish landings in South Carolina. The commercial value of clams, in shell, for Georgetown County represented about 30.6 percent of the total value of clams for the State. About $587,557 in shrimp, heads on, was landed in Georgetown County in 1981. Commercial landings of oysters and crabs occur mainly in Charleston and Beaufort Counties.

f. Farm Products. In 1978 7,659 farms were recorded in BEA Economic Area 033, a decline of 1,291 farms since 1974. The number of farms declined in all nine counties of the BEA area, but the total value of crops and livestock increased by nearly 33 million dollars. In 1978 the total value of crops in the nine-county BEA area represented about 47 percent of the state total, excluding Georgetown County. The data for Georgetown County was not reported.

g. Existing Education Levels. In 1980 the average median year of school completed for the BEA Economic Area 033 was 11.5 years. The median year of school completed for Georgetown County was 12.0 years, slightly higher than the nine county average.

In Georgetown County about 6,132 persons age 25 years old and over had completed four years of high school in 1980. About 41 percent of this group completed 4 or more years of college.

6. Employment. Total employment in BEA Economic Area 033 was 153,129 persons in 1969. By 1978, total employment had increased to 202,447 persons, an increase of 49,318 persons. However, agricultural employment decreased from 16,676 persons in 1969 to 12,898 persons in 1978, a decrease of 3,778 persons. The principal increases in employment in the private nonfarm sector were in manufacturing, retail trade and services. The number of state and local government employees increased by 8,430 employees between 1969 and 1978, but federal civilian and military employees increased by a total of only 273 employees.

Total employment in Georgetown County increased from 11,543 persons in 1969 to 15,650 persons in 1978, an increase of 4,107 persons. The civilian labor force for the years 1981, 1982, and 1983 is 17,980, 19,800 and 22,640 respectively. The percent of the labor force unemployed for the same years is 12.7, 16.1 and 13.6 percent respectively. Considerable increases in employment occurred in durable-goods manufacturing, retail trade and services. In 1980, the total number of establishments in Georgetown County was 784. Only three establishments reported 1,000 or more employees. About 454 establishments reported 1-4 employees.

7. Commerce and Transportation.

a. Waterborne Commerce. From 1972 to 1981 the trend in water- commerce for the port of Georgetown was downward. Between 1972 and 1976 average tonnage was about 1.5 million tons. Between 1977 and 1980 the ge tonnage was about 1.2 million tons. The total 1981 tonnage of 746,157 was about 300,000 tons below the total 1980 tonnage. This reduction in age occurred mainly in the Iron Ore and concentrates category. The port has ntly been active in handling wood and wood products, paper products, petro- products, and steel.

Depth of water alongside the berths and in the turning basin feet MLW. Access to the open sea is via a channel approximately 12 miles through Winyah Bay with a controlling depth of 27 feet and no height ance obstacles.

The Atlantic Intracoastal Waterway passes through Winyah Bay. ontrolling depth of the waterway in this segment, between Charleston, S. C. ape Fear River in North Carolina, is 12 feet.

b. Ship Movements and Types. Records of current (1983) ship and traffic in Winyah Bay kept by the South Carolina State Ports Authority and eorgetown Branch of the Harbor Pilots Association show that 67 visits were to Georgetown during the year by those vessels engaged in commerce. Trade s followed by the vessels included Europe and South America. Of the 67 s, 40 were made by barges (60%). Thirty-eight of the barge trips and three he trips made by ships were to deliver petroleum. The petroleum carrying s came up the Intracoastal Waterway from Charleston Harbor.

c. Ship Accidents. In recent years there have been numerous dings in the Winyah Bay area, including one that was of such a severity in as to be termed an accident. Two groundings in the past year have been ted to the local Coast Guard Station. None of these groundings resulted in measurable damage to the hulls of the grounded ships due to the softness of hannel bottom.

d. Transportation.

(1) Highways. The two major Interstate Highways serving the rn quadrant of S.C. are I-26 and I-95. I-95 is the principal interstate paralelling the Atlantic Coast from Maine to Florida. It is accessible Georgetown County via U.S. 521. The City of Georgetown is approximately 66 from I-95 via U.S. 521.

I-26 provides interstate service northward toward the st and can be reached from Georgetown County via U.S. 17 to Charleston. is approximately 60 miles from the City of Georgetown via U.S. 17.

U.S. 17 is a major coastal highway serving the port and rt areas along the Atlantic Coast from Virginia to Florida. This highway s through Georgetown County and the City of Georgetown. It is a four lane, ed highway for its entire length through the County, and it passes through and Strand resort area to the north and through Charleston to the south.

Other primary highway access is provided by U.S. 17 nate westward north of Charleston, S. 521 westward to I-95, and U.S. 701 thward through Conway into North Carolina.

Refinery access would be via State Highway 42 which is a dary state highway connecting with U.S. Highway 17 just south of eorgetown. Traffic on Highway 42 currently averages 2,000 cars and 180 trucks day. The majority of truck traffic on Highway 42 is associated with a local quarry but 24 trucks per week use Highway 42 to service the Santee Cooper rating plant located approximately three miles from U.S. Highway 17.[4]

[4] ommunity Profile of Georgetown, S.C., Wilbur Smith & Associates, 1981.

(2) Rail Service. Rail service in the County is provided by the Seaboard Coast Line Railroad. A main north-south line between Charleston and Wilmington runs through Andrews. A line runs from Andrews to Georgetown to the port, serving several industrial sites in addition to the port. A major spur runs from this line along the south side of the Sampit River to the S.C. Public Service Authority electricity generating plant, providing rail access along the Pennyroyal Road area and to industrial plants in that vicinity.

(3) Air Transportation. Air transportation in the County is provided by the general aviation facilities at Georgetown and Andrews. Commercial air transportation is available at Charleston and Myrtle Beach. The Georgetown County Airport, located three miles south of Georgetown near U.S. 17, has three 5,000 foot runways, one of which is lighted. The Andrews Municipal Airport is located one mile east of Andrews on State Road 20. It has one 3,400 foot runway. The Grand Strand Airport at Myrtle Beach, about 30 miles north of the City of Georgetown provides full commercial service. It is served by Piedmont Airlines and two commuter carriers. The Charleston Airport, about 70 miles from the City of Georgetown, also provides full commercial service. It is served by Delta, Eastern, and Piedmont Airlines and two commuter carriers.

(4) Ports and Waterways - General. The S.C. State Ports Authority operates the public terminal at Georgetown. The terminal is on the south bank of the Sampit River about one half mile from downtown Georgetown.

The terminal includes two 500-foot berths and a liquid bulk discharge facility used for receipt of petroleum products. One of the berths is leased to Georgetown Steel and the other is available for public use. Additional facilities include a 60,000 square foot transit shed, a rail loading platform, 6 truck loading bays, one 75-ton gantry crane, and 16 acres of paved outdoor storage. Stevedoring is done by a private contractor.

(5) Motor Freight. A number of trucking companies provide service to the County. Typical motor freight delivery times are as follows:

Atlanta	1 day
New York	1 day
Philadelphia	1 day
Chicago	2 days
Detroit	2 days
Houston	3 days
San Francisco	5 days

(6) Intercity Bus Transportation. Greyhound Bus Lines provides bus passenger and freight service. Major interchange points for passengers and freight are generally at Charleston or Florence.

G. Aesthetics and Noise

1. Aesthetics. The effects of the construction of the proposed refinery on aesthetics are related to site clearing activities, noise from pile driving and heavy equipment, and an increase in vehicular traffic. A temporary unsightly turbidity in the Sampit River will result from ditching for pipe placement. The erection of process equipment, exhaust gas stacks, etc. will also present some visual aesthetic impact.

2. Noise. The proposed refinery site at Harmony is located on an old abandoned rice plantation. The nearest residence is approximately three-quarters of a mile away. This proposed site is a cutover woodland with scattered rural residences. The closest subdivision with more than two houses is over one mile away. Myrtle Grove, an alternate refinery site, is approximately 1.5 miles to the east of Harmony. Two major industries, Georgetown Steel and

International Paper are located across the Sampit River app... tely 2.5 miles northeast of the Harmony Plantation site. A petroleum produ... orage facility owned by Hess Oil Company and the South Carolina State Port... hority Pier No. 31 is located in this same area. Several small industrial ... es are located along Highway #521 north of the proposed site. A coal-fi... steam electric generating station operated by the South Carolina Public Se... e Authority is approximately 1.5 miles away to the southeast.

Ambient noise has not been measured at the pr... Harmony site nor at the alternate site at Myrtle Grove. However, on th... is of measurements at other similar sites, it is estimated that pre... ay-night noise levels at either site are between 10 - 20 decibels.

H. Climate

The climate at Myrtle Beach Air Force Base, t... les north of Georgetown, during the period November 1942 - February 19... summarized in Table VI. H-1.

1. Seasonal Precipitation. The total annual ... tation is 52 inches. Of this, 31 inches, or 60 percent, usually ... pril through September. In two years out of ten, the rainfall in April ... September is less than 15.5 inches. The heaviest one-day rainfall ... he period of record was 8.8 inches at Georgetown on October 15, 1954. T... orms occur on about 50 days each year, and most occur in summer. Snow... rare. In 90 percent of the winters, there is no measurable snowfall. ... percent, the snowfall, usually of short duration, is little more than a ... The heaviest one-day snowfall on record was more than 11 inches.

2. Wind Patterns. Wind speed and direction sho... dominance of south through the spring and summer with a shift to the n... gh fall and winter, Table VI. H-1. The average yearly mean wind spee... years 1942 through 1981 is approximately 5 knots.

3. Hurricanes, Storm Surges, and Tornadoes

a. Hurricanes. Three hurricanes have af... e coast of South Carolina in recent years. They were: Hazel - Oc... 4, Gracie - September 1959, and Agnes - June 1972. Hazel caused heavy ... damage from flooding and high winds which reached 106 miles per h... tle Beach. Hurricane Gracie entered the south coast of South Carolin... ge effects and relatively little damage north of Georgetown. The pri... ts of Agnes were rain and flooding.

b. Storm Surges. The storm surge associat... rricanes is a great dome of water often 50 miles wide that comes ... across the coastline near the area where the eye of the hurricane ... fall. Many factors are involved in the formation and propagation of ... ge such as the strength of the storm, bottom conditions where the st... shore, and the position of the storm center in relation to the shor... Hurricane Camille in 1969, a 25-foot storm surge inundated Pass Chri... Mississippi. Lesser heights are more usual to the South Carolina coast.

c. Tornadoes. From 1950 to 1982, five tor... red within a 50-mile radius of Georgetown. The mathematical chance ... fic location will be struck by a tornado in any one year is quiet ... or example, the probability of a tornado striking a given point in the ... frequently subject to tornadoes is about once in 250 years.

CB DATED JUL 75 OBSOLETE

PREPARED BY: USAFETAC AUGUST 1981	STATION NAME: MYRTLE BEACH AFB SC LOCATION: N33 41 W 78 56	PERIOD: NOV 42-FEB 81 B ELEV: 26 FT	STN LTRS: MYR WBAN NO.: 13717 WMO NO.

AWS CLIMATIC BRIEF

MONTH	Temp (°F) Mean Daily Max	Temp Mean Daily Min	Temp Mean Monthly	Temp Extreme Max	Temp Extreme Min	Precip (In) Monthly Mean	Precip Monthly Max	Precip Monthly Min	Precip Max 24 Hrs	Snowfall (In) Monthly Mean	Snowfall Monthly Max	Snowfall Max 24 Hrs	Mean Rel Humidity (%) LST 09	Mean Rel Humidity (%) LST 13	Mean Vapor Pressure (In Hg)	Mean Dew Pt (°F)	Pressure Altitude (FT) M 75%	Surface Winds Pvlg Drctn (16 PT)	Surface Winds Speed Mean (KT)	Surface Winds Speed Max (KT) DD	Mean Cloud Cover (tenths)	Days Precip ≥ 0.01	Days Precip ≥ 0.5	Days Snowfall ≥ 0.1	Days Snowfall ≥ 1.5	Days Thunderstorms	Days Fog Vsby < 7 MI	Days Temp Max ≥ 90	Days Temp Max ≥ 85	Days Temp Min ≤ 40	Days Temp Min ≤ 32
JAN	56	37	47	82	13	3.5	8.2	.4	3.6	*	1	1	76	59	.20	35	550	N	5	47	6	10	2	*	0	1	14	0	0	19	12
FEB	58	38	48	83	9	3.2	7.5	.9	2.9	*	4	3	74	53	.21	36	550	N	6	90	5	9	2	*	*	1	12	0	0	16	10
MAR	66	45	54	88	19	3.7	9.4	1.1	3.4	*	6	5	80	58	.31	46	600	S	6	46	6	11	3	*	*	2	14	0	*	10	4
APR	72	53	63	93	28	2.5	7.1	.1	3.0	0	0	0	78	52	.39	52	550	S	6	41	5	7	2	0	0	3	12	*	1	2	*
MAY	79	61	70	98	36	3.7	11.4	1.0	2.9	0	0	0	84	61	.54	61	400	S	5	51	6	9	2	0	0	5	14	1	5	*	0
JUN	84	68	77	104	48	5.2	10.2	1.1	7.6	0	0	0	85	65	.71	69	350	S	5	50	6	10	3	0	0	8	14	5	14	0	0
JUL	87	72	80	101	54	6.5	16.4	1.6	6.3	0	0	0	86	64	.79	72	250	S	4	46	6	13	4	0	0	11	13	8	23	0	0
AUG	87	71	79	104	54	5.6	14.6	1.1	6.5	0	0	0	86	66	.79	72	200	S	4	42	6	11	3	0	0	10	16	6	22	0	0
SEP	83	67	75	99	42	5.5	11.7	1.0	6.9	0	0	0	85	60	.69	68	300	NNE	4	56	6	9	3	0	0	5	16	2	12	0	0
OCT	75	55	65	93	25	2.9	10.3	*	8.2	0	0	0	83	56	.44	55	400	N	4	37	5	6	2	0	0	1	14	*	1	2	*
NOV	66	44	55	85	16	2.7	9.7	.0	9.4	*	*	*	81	55	.32	47	400	N	4	40	5	6	1	0	0	1	13	0	*	10	5
DEC	58	38	48	81	11	3.3	6.5	.3	[illegible]	*	1	1	76	55	.24	39	550	N	5	47	5	9	2	*	0	*	13	0	0	19	11
ANN	77	54	65	104	9	48.3	16.4	.0	9.4	*	6	5	81	55	.42	55	450	S	5	90	6	113	29	*	*	48	165	22	78	78	42
EYR	35	35	35	35	35	35	35	35	35	32	32	32	9	10	10	10	10	10	10	25	10	35	35	32	32	32	32	35	35	35	35

REMARKS

RUSSWO FOR
HOURLY OBS: Mar 49-Dec 70, Jan 73-Feb 81
DAILY OBS: Nov 42-Jul 47, Jan 49-Dec 54
Nov 56-Feb 81

NUMBER OBSERVED WITHIN: (1900-1979)	A/B	MAY	JUN	JUL	AUG	SEP	OCT	NOV	ANN
	60NM	0/0	0/0	1/3	1/2	3/3	2/2	0/0	7/12
(A) Hurricanes	120NM	0/1	0/5	3/6	5/9	2/9	3/6	0/1	14/37
(B) Tropical Storms	240NM	1/4	3/10	4/7	18/19	14/28	8/16	1/1	49/75

NOTE: · DATA NOT AVAILABLE # AMTS < UNITS SHOWN IN HEADING ** INSTANTANEOUS PEAK WINDS $ % CALM GRTR % PVLG DRCTN ‡ BASED ON < FULL MONTHS

CAT FREQ (%)	HRS LST	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	EYR
CEILING LESS THAN 3000 FT AND/OR VISIBILITY LESS THAN 3 MI	00-02	20	12	18	12	13	8	3	5	13	10	15	18	12	9
	03-05	21	17	22	13	17	14	7	10	18	16	17	19	16	9
	06-08	25	18	24	13	17	13	9	17	26	20	20	19	18	10
	09-11	24	18	19	8	10	9	5	8	13	12	15	18	13	10
	12-14	22	16	15	5	7	7	3	6	12	8	12	16	11	10
	15-17	21	14	12	5	7	7	4	5	9	6	12	17	10	10
	18-20	20	12	14	5	7	6	4	7	9	6	13	16	10	10
	21-23	19	13	16	7	9	4	2	5	10	7	13	18	10	10
	ALL HRS	22	15	18	9	11	9	5	8	14	11	15	18	13	
CEILING LESS THAN 1500 FT AND/OR VISIBILITY LESS THAN 3 MI	00-02	16	9	13	8	9	5	1	3	7	8	13	15	9	9
	03-05	17	13	17	10	13	9	4	7	15	14	14	16	12	9
	06-08	21	15	21	9	13	11	8	14	22	17	18	15	15	10
	09-11	21	14	15	4	7	5	3	5	8	9	12	14	10	10
	12-14	17	12	11	2	5	4	1	2	6	4	9	10	7	10
	15-17	16	10	9	3	5	3	2	2	5	4	8	11	7	10
	18-20	16	10	12	2	4	2	1	4	5	3	8	13	7	10
	21-23	14	10	13	4	5	2	1	3	6	5	10	14	7	10
	ALL HRS	18	12	14	5	8	5	3	5	9	8	12	14	9	
CEILING LESS THAN 1000 FT AND/OR VISIBILITY LESS THAN 2 MI	00-02	13	7	10	5	5	3	1	2	4	6	11	11	7	9
	03-05	14	10	12	7	8	7	2	4	11	9	12	13	9	9
	06-08	19	13	16	7	9	8	4	8	14	12	15	13	12	10
	09-11	16	10	12	3	2	3	1	2	5	4	4	10	6	10
	12-14	12	6	7	1	2	2	*	1	2	1	6	8	4	10
	15-17	11	7	6	1	1	1	1	1	3	1	6	8	4	10
	18-20	12	8	8	1	2	1	*	2	2	1	5	9	4	10
	21-23	14	8	10	3	2	*	*	1	3	2	8	11	5	10
	ALL HRS	14	9	10	4	4	3	1	3	6	5	9	10	7	
CEILING LESS THAN 200 FT AND/OR VISIBILITY LESS THAN 1/2 MI	00-02	2	2	2	1	0	*	0	0	*	1	2	1	1	9
	03-05	2	2	4	2	2	1	*	0	1	1	2	1	2	9
	06-08	4	2	3	1	1	*	*	1	2	2	2	2	2	10
	09-11	2	1	1	0	0	0	0	0	0	0	*	*	*	10
	12-14	*	*	0	0	0	0	0	0	0	0	0	*	*	10
	15-17	*	*	*	0	0	0	0	0	0	0	*	*	*	10
	18-20	2	1	1	0	0	0	0	0	0	0	1	1	1	10
	21-23	3	1	2	*	0	0	0	0	0	*	1	2	1	10
	ALL HRS	2	1	2	1	*	*	*	*	*	1	1	1	1	

AWS FORM APR 74 62
PREVIOUS EDITION IS OBSOLETE

TABLE VI. H-1

I. Cultural Resources

The Georgetown area is rich with historical features dating back to 1719 - 1720, the approximate time of the founding of settlements which later became Georgetown. The first settlers did not arrive as groups, but rather, were drawn individually by the prospects for profit in agriculture, Indian trade, and naval stores. Some of the French Huguenot and English settlers were second generation landed gentry from Berkeley and Colleton Counties, while others had pushed north from Charleston as investors in the newly developing economy. Many of the Scottish settlers were immigrants. The Huguenots of the early district were alkready rice planters, while the Scots were landholders, officeholders, and merchants. All soon became a part of the rice and indigo cultures which were to form the backbone of the area from the 15th to the mid-19th centuries.

Situated southwest of the city limits of Georgetown is a tract of land known as Harmony Plantation. Harmony Plantation, bordered by the Sampit River (north), Pennyroyal Road (south), and Turkey Creek (west), (see Figure VI. I-1) was a minor holding throughout its rice cultivation history, although its owners became quite well-to-do during the golden era of rice (mid-19th century). Historically neglected, the property supported at least one antebellum slave settlement - postbellum tenant settlement, but no "great house" complex, industrial area or commissary. The focal settlement and subsistence zone during both the prehistoric and historic periods appears to have been the Sampit River frontage where at least three archaeological sites (Figure VI. I-1) have been locally reported and studied.[5]

J. Geology and Topography*

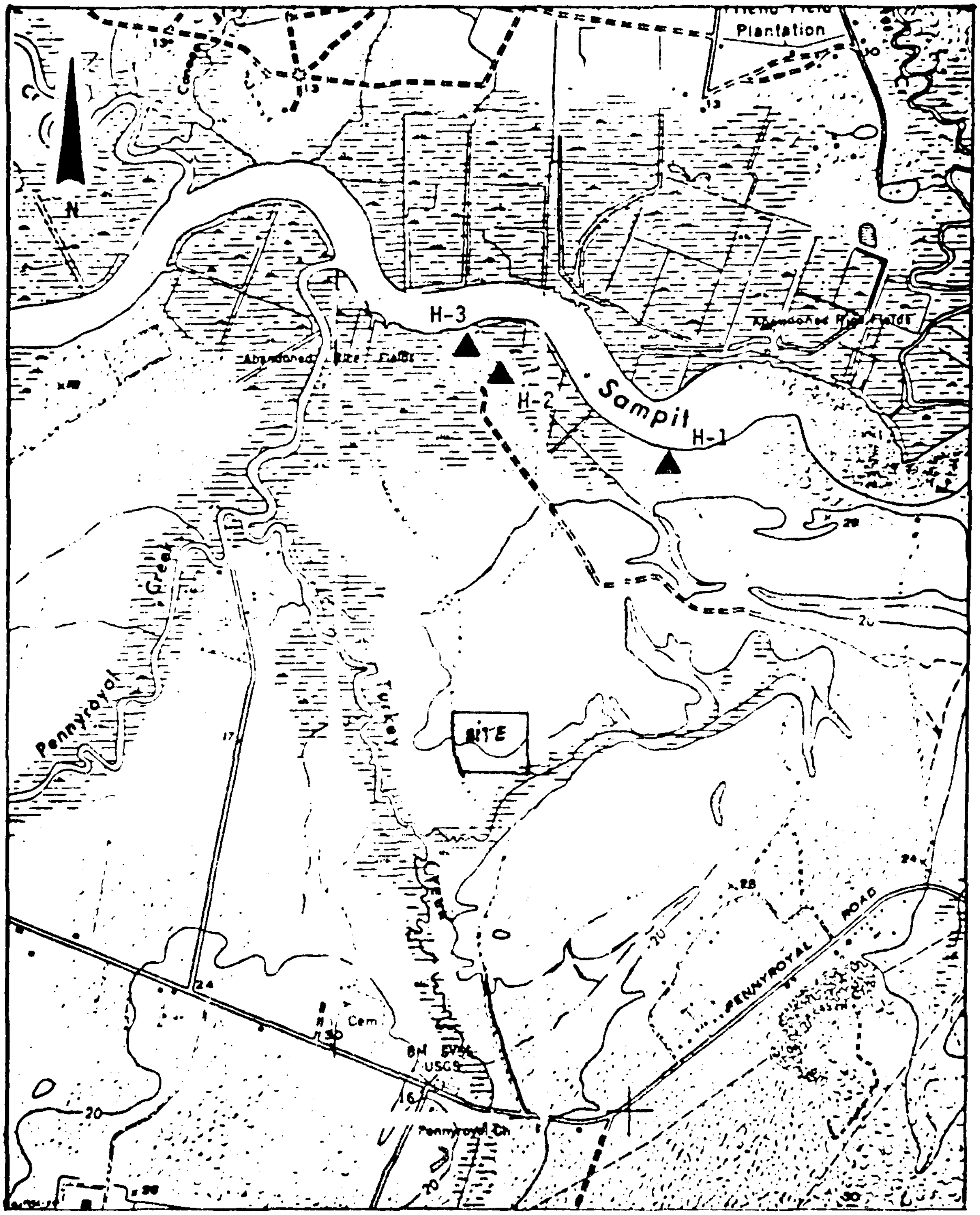
1. Geomorphology. The main surface drainage in the area is the Sampit River which empties into Winyah Bay at Georgetown. The principal tributaries to the Sampit River in the study area are: Pennyroyal Creek and Turkey Creek which join together before entering the Sampit River, and Whites Creek which empties into the Sampit near Georgetown.

The highlands are nearly level to gently sloping and consist of moderately to excessively well-drained soils, whereas lowlands along the flood plain of the Sampit River are nearly level and poorly drained (Stuckey, 1980). The forest cover in the highlands is predominantly pines and hardwood trees, whereas the lowlands consist of marshland and swamps.

The channel depth of the Sampit River at low tide ranges from about 25 to 35 feet in the lower 3 miles of the river (Johnson, 1978), and the width of the river is about 1,500 feet where it empties into Winyah Bay and narrows to about 500 feet at about 6 miles inland.

2. Stratigraphy. The surficial geology consists of Pleistocene to Holocene (Recent age) fluvial and marine deposits. The sedimentary sequence overlying basement rocks in the Winyah Bay area is composed of unconsolidated and consolidated sand, clay, limestone, and sandstone sediments that range in age from upper Cretaceous to Recent. Table VI. J-1 describes the stratigraphic sequence of the Winyah Bay area as discussed by Johnson and Du Bar (1964) and Zack (1977).

[5] Cultural Resources Investigation at Harmony Plantation, Carolina Archaeological Services, March 26 1981.



KNOWN ARCHEOLOGICAL SITES ON SAMPIT RIVER FRONTAGE

Source: Cultural Resources Investigation at Harmony Plantation, Carolina Archaeological Services, March 26, 1981.

FIGURE VI.F-4

a. Upper Cretaceous Formations. The upper Cretaceous Formations in Georgetown County rest on the basement rock and consist, in ascending order, of the Middendorf Formation, the Black Creek Formation, and the Peedee Formation (Zack, 1977). The total thickness of the upper Cretaceous Formations is about 1,800 feet.

The Middendorf Formation contains layers of medium to coarse sand and silty clay. An isopleth map by Zack (1977) shows the top of this formation at about 1,100 feet below sea level in the Winyah Bay area. The thickness of the formation in this area is about 700 feet.

The Black Creek Formation, which rests on the Middendorf, is the principal source of potable water in the area. The formation consists of laminated, dark-gray clay interbedded with gray to white, fine to very-fine glauconitic, phosphatic, and micaceous quartz sand. The upper surface of this formation in the Winyah Bay area is at an altitude of about 450 to 500 feet below sea level.

The Peedee Formation, about 250 feet thick, is composed of dark gray, fine, clayey sand with semi-consolidated interfingering sandstones and limestones. Glowacz and others (1980a, p.13) report the base of this unit near the city of Georgetown to lie at a depth of about 726 feet below sea level. Zack (1977) indicates that the base of the Peedee Formation is about 480 feet below sea level at a test well drilled for the city of Georgetown.

b. Tertiary Formations. Throughout most of Georgetown County, thin beds of fine clayey sand, fine calcareous sand, and coquinas of Tertiary age overlie the Peedee Formation (Zack, 1977). These Tertiary formations include the Black Mingo Formation, Santee Limestone, and Duplin Marl. At one time the Duplin probably covered the entire area, but temporary transgressions of the sea across the land surface have eroded away most of these sediments (Cooke, 1936). Thickness of these formation is not available in the vicinity of Georgetown, South Carolina. Zack (1977) included the Tertiary and Holocene sediments with a thickness of 210 feet as one unit in his geologic cross section of the area.

c. Quaternary Sediments. Overlying the Tertiary Formations are sands, marls, limestones, silts, and clays. These sediments make up terrace complexes which were deposited at different stands as sea level fluctuated during Pleistocene time (Glowacz and others, 1980).

Fine-grained sands in the Winyah Bay area can be traced north eastward to the North Carolina State line. These sediments form a "dune belt" which was termed the Myrtle Beach Bar by Johnson and Du Bar (1964). Figure VI. J-1 shows a cross-section profile (A-A') of Quaternary sediments across the Sampit River between Turkey Creek and Georgetown. This cross section shows that most sediments above mean sea level are composed of sand. The sediments below sea level are fossiliferous sand, calcareous silt, or marl and limestone.

3. Ground Water

Large quantities of ground water are available in the saturated sediments at Georgetown County. Artesian conditions occur in the deep sediments, and a free water surface (water table) occurs in the shallow sediments. Only the shallow aquifers in the Winyah Bay area are recharged locally. Deeper artesian aquifers are recharged in outcrop areas near the Fall Line and have lenses or beds of clay that retard downward migration of contaminates from the surface. The refinery would use about 973,000 gallons of process water per day which would be obtained from deep wells on the refinery site. Because the site is located within a Groundwater Capacity Use Area, a permit would be required from the S.C. Water Resources Commission for withdrawals exceeding 100,000 gallons per day.

The Middendorf encompasses several high-yielding aquifers, but the contained water is salty in the study area. Most of the potable water supply for municipal or industrial purposes in the area is withdrawn from the Black Creek aquifer (Table 1). The aquifer responds as an artesian system, and the quality of the water is acceptable for most uses. Withdrawal of ground water in the Georgetown area has lowered water levels to 50 feet below sea level (Zack, 1977).

Another source of artesian water is the Peedee Formation. Although large quantities of water are available from the Peedee aquifer system, it is only used locally due to excessive concentrations of iron, hydrogen sulfide, and sulfate in the water (Zack, 1977).

In the Georgetown County area, both water table and artesian aquivers occur in the shallow Tertiary and younger sediments that supply potable water to private domestic wells. The water-bearing sands of these aquifers are often discontinuous and are recharged primarily by local precipitation.

The shallow water-table aquifer occurs in the near surface sandy sediments. Ground water is discharged from the shallow aquifer by evapotranspiration, pumping, and seepage to surface-water bodies. The greatest loss of water by evapotranspiration probably occurs between the months of May to September when ambient air temperatures are above 70°F. The general direction of water movement in the shallow water-table aquifer is to discharge points in low areas such as streams or swamps.

The shallow aquifer in the study area is composed of well sorted, fine to medium-grained sands. Glowacz and others (1980a) report that the transmissivity of the shallow aquifer is about 1,340 ft^2/d in the very permeable sand and much less in finer soils. These authors also state that the rate of ground-water flow in the shallow aquifer is about 1 ft/d with a very low or nearly level hydraulic gradient.

South Carolina Department of Health and Environmental Control, Office of Enviromental Quality Control, Ground-Water Protection Division, has established a network of shallow water-quality monitoring wells in Georgetown County (Glowacz and others 1980a). These wells were used to investigate potential pollution from land disposal of wastes. An evaluation, by this State agency, of the background water-quality data indicates that the shallow aquifer in several areas in Georgetown County has potential for drinking water supplies. One of these areas is located in the Pennyroyal Road section.

Table VI. J-2 lists chemical constituents and physical properties of water from wells in the vicinity of Pennyroyal Road (Glowacz and others 1980a). Water analyses from these three wells indicate that dissolved solids, hardness, specific conductance, and pH increase with depth. Well W10-yl, which is screened at 42 feet, had the greatest amount of total dissolved solids. Total dissolved solids are less near land surface than at depth and indication that local precipitation is the source of recharge to the shallow aquifer.

The shallow aquifer system south of Georgetown is important as a suitable source of domestic water. However, the chemical quality of the water is variable. Some water may need treatment for iron, but in most cases, the water is suitable for drinking supplies.

4. Seismicity

The characteristics of South Carolina seismicity may be explained by assuming that earthquakes occur when regional tectonic stress exceeds the shear strength of rock within zones of weakness. These weak areas are presumed to be zones of pre-existing failure in the basement rocks underlying the Coastal Plain (Tarr and others, 1981).

The Winyah Bay area has been defined by Tarr (1977) and Tarr and others (1981) to be within the Georgia-South Carolina seismic zone. Tarr (1977) defines a seismic zone approximately 500 km long and 350 km wide that extends on a northwest-southeast oriented longitudinal axis that passes through the cities of Charleston, Bowman, and Orangeburg. This zone covers the entire State of South Carolina and the northeast edge of Georgia. Figure VI. J-2 shows that significant seismic activity has occurred only in the Charleston-Summerville and Orangeburg-Bowman areas.

From March 1973 through December 1979 significant activity occurred within the two previously defined areas. In addition, seismic activity occurred in the vicinity of Clark Hill Reservoir on August 2, 1974, as shown on Figure VI.J-2. Current seismicity seems to be concentrated in clusters rather than

TABLE VI. J-1

--Stratigraphic units of the Lower Coastal Plain, Georgetown County, South Carolina

System	Series	Geologic unit	Description of sediments	Associated aquifers	Water-bearing properties
Quaternary	Holocene	Undifferentiated	Surface soil with forest litter cover.	None (well drained)	None
	Pleistocene	Terrace deposits (Myrtle Beach Barrier)	Sorted fine to medium, well drained sands.	Shallow water table which can range from zero to a few feet below land surface.	Freshwater derived from local precipitation. Water may contain iron.
Tertiary	Upper Tertiary	Undifferentiated	Sands, silts, marls, and dark clays.	Water table and artesian aquifers. Primarily in inland Horry and Georgetown Counties.	Water usually hard, with hydrogen sulfide odor and iron.
	Middle Eocene	Santee Limestone	Occurs only in inland Georgetown County; fossiliferous and calcareous.	Fractured carbonate-rock aquifer. Water table and artesian conditions.	Hydraulic properties undetermined. Supplies water to domestic wells in southwest Georgetown County.
	Lower Eocene and Paleocene	Black Mingo Formation	Greenish-gray glauconitic sands with thick beds of coquina (loose fossiliferous limestone). Occurs primarily in Georgetown County.	Shallow water table and artesian aquifers primarily in Georgetown County (possible hydraulic connection with Peedee aquifer system locally).	Water quality usually poor, but yields are high.
System	Series	Geologic unit	Description of sediments	Associated aquifers	Water-bearing properties
Cretaceous	Upper Cretaceous	Peedee Formation (Navarroan and Tayloran age)	Gray to greenish-black calcareous glauconitic clayey silts and fine-grained sands with thin beds of gray calcareous sand and hard sandy limestone.	Peedee aquifer system.	Treatment for iron and sulfate removal required for municipal use. Yields are high.
		Black Creek Formation (Tayloran and Austinian age)	Gray to greenish montmorillonitic clays and thin beds of gray to white slightly glauconitic sand. Thin beds of hard, sandy limestone containing pyrite, lignite, and possibly collophane.	Black Creek aquifer system.	Principal aquifer in the two-county area. Contains saline water in northeastern Horry County. Yields as high as 1000 gallons per minute have been obtained in Horry County. Fluoride is usually high.
		Middendorf Formation	Light-colored cross-bedded kaolinitic sands with lenses of white massive kaolin. Lignite and pyrite common. Clays are non-calcareous.	Middendorf aquifer system.	Contains salty water throughout area (possible exception along northwestern boundary of area).
Pre-Cretaceous		Basement	Basement rocks (metamorphic crystalline complex).	None	None

References: Adapted from Cooke, 1936; Stringfield, 1966; Maher, 1971; and Zack, 1977.

—Laboratory water analyses from selected wells in the vicinity of Winyah Bay area, Georgetown County, South Carolina[a] (results in parts milligrams per liter except specific conductance and pH)

Well number	Screen depth in feet	Total organic carbon	Lead	Iron (Fe)[b]	Total phosphate	Calcium (Ca)	Magnesium (Mg)	Sodium	Alkalinity as $CaCO_3$	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$	Specific conductance[c]	pH
W10-y1	42	5	<0.05	0.2	0.07	50	4	20	174	<10	12	<0.1	1.48	220	140	300	7.1
W10-y2	23	<3	<0.05	0.7	0.07	9	0.9	15	31	10	13.5	<0.1	—	80	26	115	6.0
X10-f1	13	<3	<0.05	0.3	<0.02	10	1.0	3.2	34	10	4	<0.1	<0.02	59	29	85	6.2

[a]Analyses reported by Glowacz, M. E., and others, 1980.

[b]In solution at time of analysis.

[c]Micromhos at 25°C.

TABLE VI. J-2

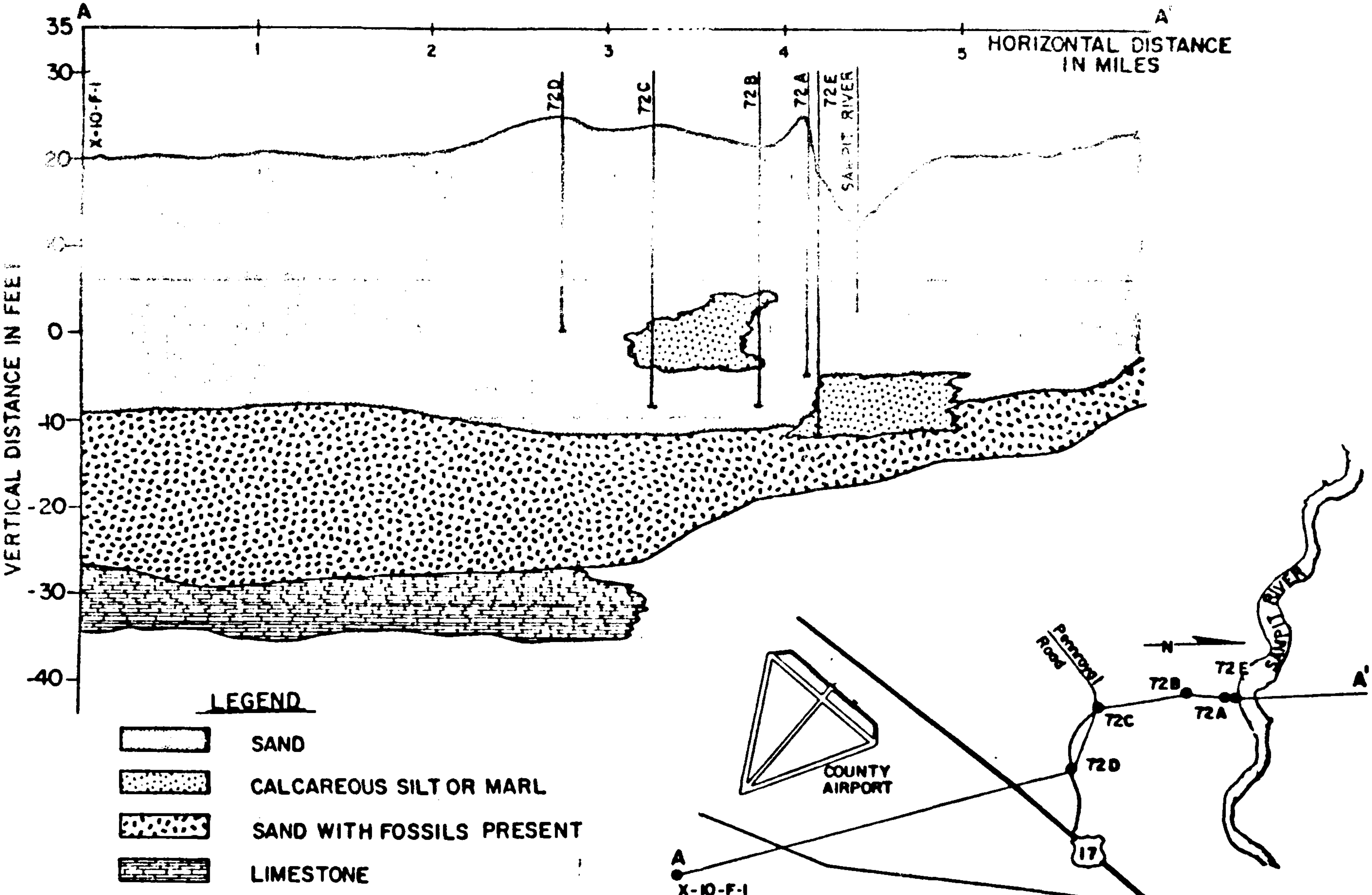


FIGURE 2.--LITHOLOGIC SECTION ALONG A-A' IN IN VICINITY OF SAMPIT RIVER NEAR GEORGETOWN SOUTH CAROLINA (GLOWACZ, M.E. AND OTHERS, 1980)

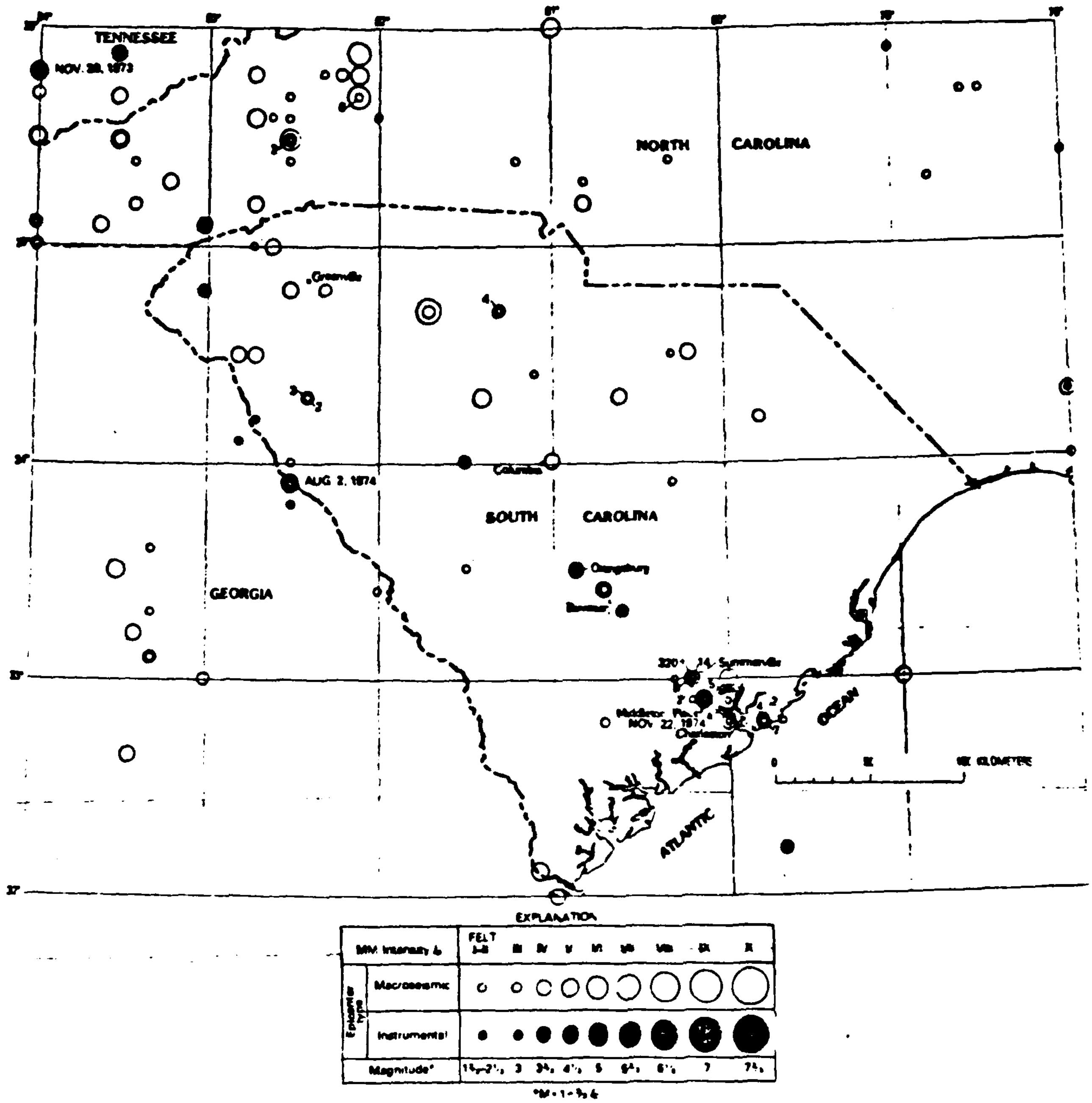


FIGURE 3.—Seismicity in South Carolina and adjoining States, 1754–1975. Earthquakes are indicated by circles of varying sizes, which represent the maximum Modified Mercalli intensities shown in the explanation. Numbers beside the epicenter symbols show the number of events recorded. Earthquakes are from the catalog of Bollinger (1975), supplemented by earthquakes reported by Carver and others (1977) and Bollinger and Visvanathan (this volume).

The macroseismic epicenters were determined from accounts of damage and felt reports, whereas instrumental epicenters were determined from seismographic data. Tarr (1977).

FIGURE VI. J-2

distributed along a northwest-trending fault zone. Major seismic activity has not been detected in the Georgetown area.

K. Research Institutes

Much of the area surrounding Winyah Bay is being managed by the State for wildlife forestry research and other natural science studies. Proximity of the lower Winyah Bay area to large natural areas such as the Francis Marion National Forest and an undisturbed seashore stretching almost to Charleston makes it unique and ideal for environmental studies.

HOBCAW BARONY

Hobcaw Barony is a 27,500 acre preserve which is located on the Waccamaw Neck peninsula. Miss Belle W. Baruch, willed the property and net returns from a trust fund to be used "....for the purpose of teaching and/or research in forestry, marine biology, and the care and propagation of wildlife and fauna in South Carolina in connection with the colleges and/or universities in the State of South Carolina." A long-term tripartie contract permits Clemson University to manage the forest-marine areas and the University of South Carolina to manage the marsh-estuarine areas for the Belle W. Baruch Foundation. The Forest Science Institute of Clemson and the Institute for Marine Biology and Coastal Research of U.S.C. maintain facilities and active research on the forest types, fresh water swamps, former rice fields, salt marshes, estuarine waters, estuarine islands, and barrier island which comprise this preserve. The research and instructural programs have grown over the years until they are now internationally known as a center for the study of estuaries and coastal areas. The North Inlet Estuary, which has a direct connection to Winyah Bay via several waterways, has been designated as an Ecological Experimental Reserve by the National Science Foundation and is the only marine-oriented ecosystem in the United States to be part of the long-term Ecological Research program. The presence on Hobcaw of the research and teaching program of the University of South Carolina in marine science and the forestry program of Clemson University has had a significant positive impact on the economy of Georgetown and adjacent regions.

At present the field laboratory has about 25 year-round employees with a yearly payroll of $324,000. Clemson University has approximately 24 year-round employees with an estimated payroll of $280,000. In addition, the Baruch Foundation has a staff of four persons and an estimated payroll of $25,000. The total annual payroll of these programs is approximately $629,000. All of these employees live in the Georgetown area. In addition, the U.S.C. Baruch Institute has many visiting students, senior scientists, and visitors which totaled approximately 10,000 person/days in 1982. In the past 14 years, the USC Baruch Institute has received approximately $9,000,000 as grants in support of research and instructional programs.

TOM YAWKEY WILDLIFE CENTER

Thomas A. Yawkey Property. Mr. Thomas Yawkey made provisions in his will for portions of North Island, South Island, and Cat Island to be managed by the State of South Carolina as a wilderness area and game preserve. A total of 15,000 acres is to be preserved for these purposes and a ten million dollar trust fund is to provide financial support. The will states that "...North Island is to be held and used for all time as a wilderness area. No permanent structure, human habitation or roads permitted except those necessary for protection and management of the property...no change of primitive wilderness character permitted." South Island is to be held for "...the protection and

feeding of waterfowl and no hunting and shooting allowed. No general recreation activities allowed." The remainder of the property is to be ...dedicated, held and used for a wildlife management area for migratory birds of all kinds, administered by the Wildlife and Marine Resources Department."

In addition to waterfowl management, ongoing management programs are being conducted for white tail deer and turkey. Seasonal studies of endangered species including the Bald eagle, Loggerhead turtle, and alligator are conducted by a rotating staff of State biologists. Several long-range studies are funded by private organizations including an algae study. An ecological characterization and development of management strategies for aquaculture, funded by Sea Grant, is underway and is expected to continue for another three years.

At the present time, the total cost of various management programs at the Yawkey Wildlife Center is approximately $500,000.

VII. ENVIRONMENTAL CONSEQUENCES

Air and Water Quality Analysis of Alternatives

A. Harmony Plantation, Georgetown, SC

Harmony Plantation is a siting alternative for the proposed Carolina Refining and Distributing Company (CRDC) refinery. This rural site is located approximately four km (2.5 mi) west of Georgetown, S.C. and south of the Sampit River (Figure VII-1). The site is located within the Sampit River watershed, close to Turkey Creek, Pennyroyal Creek, and their confluence with the Sampit River.

1. Effects of Plant and Pipeline Construction

The use and operation of construction equipment and trucks transporting excavated earth and construction materials would affect the air quality of the area. Construction activities contribute to levels of carbon monoxide, particulates, nitrogen oxides, and hydrocarbons. Other activities such as land clearing, welding, painting and paving also contribute to air quality impacts. These air quality impacts would be expected to be localized and of short duration. Mitigative methods including construction scheduling and specifications requiring contractors to employ control techniques to minimize fugitive dust and other emissions would limit the extent and duration of these impacts.

Construction of the plant would convert approximately 40.5 ha (100 ac) of heavily cutover forestland. This could alter drainage flow patterns into the Sampit River, tributary creeks, and adjacent wetlands. A temporary increase in erosion, with a subsequent increase in turbidity in the Sampit River, could occur as a result of wind and water runoff over large areas cleared for construction. This, in turn, could increase turbidity and sediment deposition in the upper reaches of Winyah Bay.

Some chemical and hydrocarbon pollutants could enter the Sampit River with runoff from spillage at the construction site. These pollutants may include petroleum products from crankcase oil or leaky storage containers, solvents, dust control oils, minor oil spills, pesticides, fertilizers, synthetic organic materials, metals, soil additives, and other construction pollutants. The amount of pollutants released would be dependent upon site and meteorological conditions; impacts could be mitigated by using best-management practices at the construction site.

Pipeline construction temporarily may alter runoff flow patterns during excavation. Additional effects, such as those outlined for construction of the plant, also may occur. Depending upon the pipeline route chosen, impacts to shorelines, wetlands or river bottom may create short-term localized degradation of water quality.

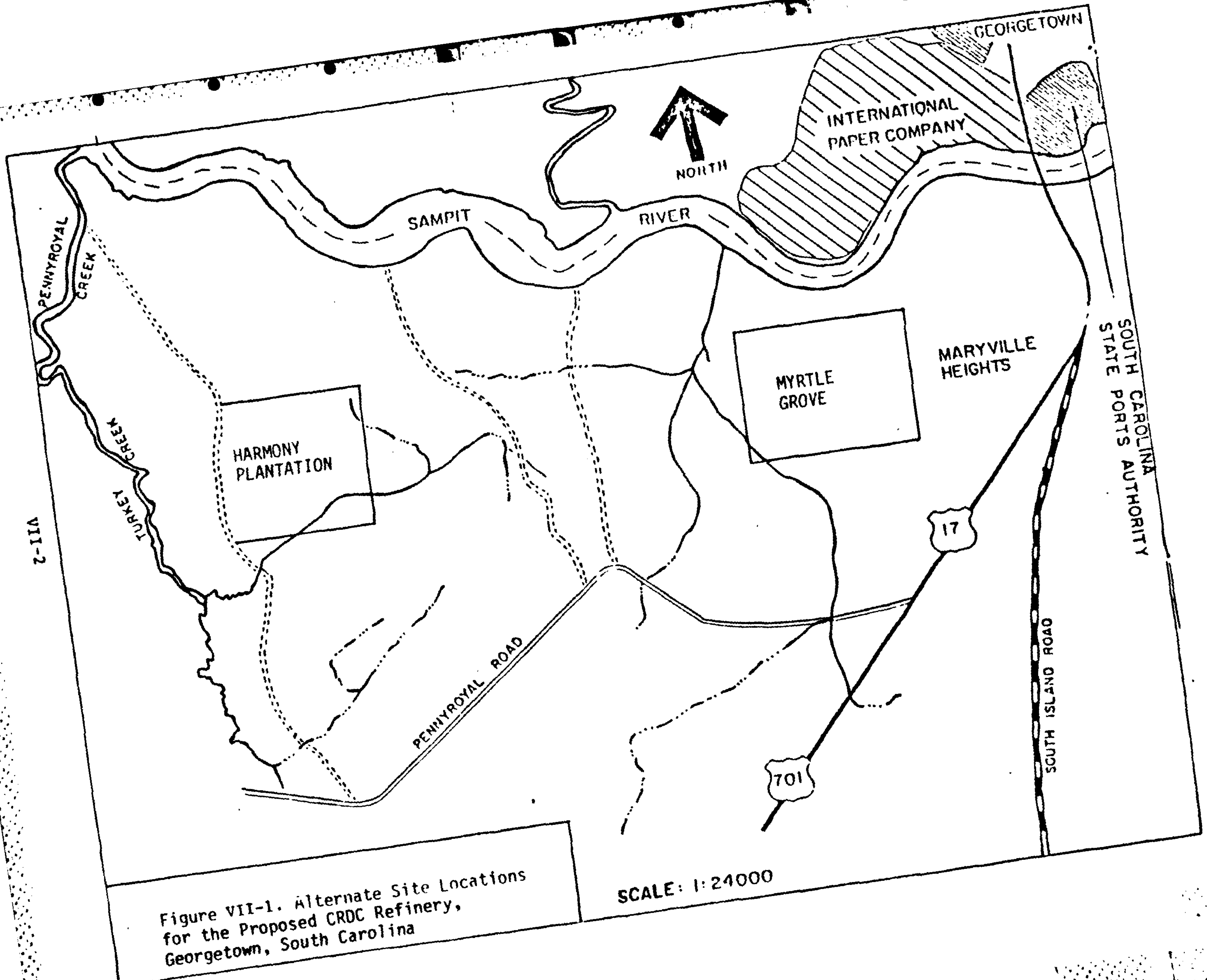


Figure VII-1. Alternate Site Locations for the Proposed CRDC Refinery, Georgetown, South Carolina

a. Pipeline Routes

(1) Under the Sampit River. The proposed plan is to cross 182.9 m (600 ft) of the Sampit River, 152.4 m (500 ft) upstream of the new U.S. Highway 17 bridge, by excavating a trench 1.8 m (six ft) in depth, using a dragline on a barge. Effects on water quality would include temporary increases in turbidity from disturbance of the river bed. Increases in chemical pollutants or BOD levels also would result with release of pollutants from disturbed sediments. The greatest impact probably would be from the release of ammonia. The highly organic composition expected for the Sampit River sediments would be conducive to the anaerobic production of ammonia; release of ammonia to the water column upon disturbance of the sediments would occur easily. Petroleum hydrocarbons, chlorinated hydrocarbons and heavy metals present in the disturbed sediments probably would not be released to any great extent. However redistribution of contaminated sediments could impact benthic communities (U.S. Army Engineer Waterways Experiment Station, 1978). Water quality impacts would be expected from the point of excavation in the Sampit River, and possibly a few kilometers upstream due to tidal water mass movement (Johnson, 1978), to the upper reaches of Winyah Bay. The duration of these impacts would be determined by flushing rates during excavation. Turbidity and pollutant levels could show a greater increase if blasting is required for trench excavation.

Another alternative for crossing beneath the Sampit River would be by tunneling. Impacts to Sampit River water quality from this method would be less than for trenching across the river. However some turbidity increases due to runoff from the tunneling sites on either shore could occur.

(2) Suspension of Pipelines from the U.S. Highway 17 Bridge. This construction alternative would have little, if any, impact on water quality in the Sampit River. Bottom sediments would not be disturbed and subsequent release of potential pollutants therefore would not occur.

(3) Around the Sampit River. This construction alternative could have indirect effects on the water quality of the Sampit River. Some turbidity and pollutant level increases may result from runoff from extensive overland excavation and disturbance of small streams and wetlands in the headwater areas. The emplacement of the pipeline through wetlands could alter sheet flow patterns, causing channelization of flow and drainage of some areas. This would impact on the wetland ecology of the affected area. Specific impacts would depend upon the actual pipeline route and construction methods chosen.

2. Effects of Plant Operation

Air quality impacts from the proposed refinery are detailed in Section VII.A. Generally, maximum pollutant impacts on air quality would occur within one km (0.6 mi) of the facility site. The air quality analysis performed indicated that there could be violations of air quality standards for non-methane hydrocarbons and ozone. The analysis also indicates the possible consumption and violations of the remaining allowable 24-hr sulfur dioxide Class II and Class I increments for the area. Section VII.A.2.c.(2)(g) beginning on page VII.A-19 presents a summary of the results of the air quality analysis.

The air quality analysis for this EIS was based on estimated facility emissions and worst case meteorological conditions. A refined air quality impact analysis using emission rates based on final design would be required by the South Carolina Department of Health and Environmental Control before the facility could be constructed. The refined analysis must show that air quality impacts are within acceptable limits.

Water quality within the Sampit River and Winyah Bay would be affected by normal plant operation, oil deliveries to the receiving pier by ship or transfer of oil from the pier through the pipeline. With the exception of normal plant operation, any impacts to water quality would be associated with accidents and spills from improper handling procedures, illegal discharges or poor "housekeeping." Normal plant operation would produce impacts to water quality from pollutant components in the wastewater discharge.

a. Wastewater Discharge. Wastewater discharge would consist of stormwater runoff from the plant, from delivery vessels at the pier, and process and blowdown water discharge from the plant.

Stormwater runoff from delivery vessels would not be treated and may add some hydrocarbon pollutants to Winyah Bay or the Sampit River, depending upon the cleanliness of the vessels. This impact would not be continuous and would be independent of the refinery site location near Georgetown.

The most recent information from the applicant indicates oil-free water from storm, sewer, boiler blowdown, cooling tower blowdown, water treatment system blowdown and deionizer blowdown would be discharged directly to the receiving waters. Oil-contaminated sewer or blowdown water would be routed through an API separator prior to discharge. Process water would be routed through an API separator, treated by aeration and flotation methods, and then discharged (Taggart, 1983).

Water quality would be impacted by the various pollutant components within the wastewater stream. The extent of this impact on the Sampit River or Winyah Bay would depend upon the actual components in the wastestream and the location of the outfall. It also should be noted that the NPDES permit would require compliance with the final New Source Performance Standards. Expected components of the various wastewaters are shown in Tables VII.B-5, VII.B-6 and VII.B-10. In-plant component levels shown in Table VII.B-5 would probably be representative for the various blowdown wastewaters if discharged directly with no treatment, as is proposed. Available alternative outfall locations for the Harmony Plantation site would include discharge to Turkey or Pennyroyal Creeks, discharge directly to the Sampit River from the closest point to the site or other points downstream to the mouth, discharge by pipeline directly to Winyah Bay, or discharge directly to the ocean.

Discharge directly to the creeks would impose a significant mass of pollutants to a water body which may not be able to provide high dilution capability. While further hydraulic studies would be required to assess specific impacts to the creeks, some concentration of pollutants within the sediments would occur and flushing of the pollutants would be slow. Impacts from discharge of wastewaters directly to the Sampit River would vary depending upon the location of the outfall in the Sampit. The further upstream the location of the outfall, the greater the

amount of Sampit River water column and sediments that would be impacted by pollutants in the wastestream. Upstream outfall locations would exhibit lower flushing rates and hence more opportunity would exist for pollutants to accumulate in the river sediments or biomass.

Downstream locations may be rapidly diluted and flushed by the tidal excursion of Winyah Bay waters. Discharge outfalls located directly in Winyah Bay would impose the least impact on the Sampit River, although some pollutants still may be carried in on the flood tide, and would have greater potential for rapid dilution. Some localized impacts to the water column and sediments would occur near the outfall in Winyah Bay. The overall environmental impact in the bay would depend upon the characteristics of the specific location chosen. Locating the outfall directly in the Atlantic Ocean would produce the least operational impact to Winyah Bay, but construction impacts to wetlands could be extensive.

The ultimate choice of outfall location may require excavation and laying of extensive outfall piping that would create impacts to water quality in the Sampit River similar to those associated with the laying of oil pipeline to the refinery site.

Impacts to water quality from the refinery discharge could be reduced, regardless of siting alternative, by employing levels of treatment for the refinery effluent above that presently proposed for the refinery. Treatment of the refinery discharge, as discussed previously, is proposed to include an API type gravity separator with air flotation added for the process waters. According to a study by Manning and Snider (1983), API separators can only be expected to achieve an effluent oil and grease concentration of about 50 mg/l. With the use of air flotation, effluent concentration of oil and grease can be brought as low as 10 mg/l under excellent conditions, but would most likely be around 24 mg/l. The addition of biological, activated carbon absorption and filtration steps to the treatment process could produce an effluent much lower in oil and grease concentration and with a significant reduction in other pollutant levels, such as for ammonia and organic compounds, as well.

Impacts of wastewater also may be reduced by alternative disposal methods, such as land application or deep-well injection of refinery wastewaters, or by incorporating wastewater recirculation in the refinery design.

In land application, wastewater is spread over a soil surface using one of a number of available spreading mechanisms. Characteristics of the soil serve to "treat" the wastewaters during percolation by removing oil, grease, solvents and related organic compounds. A groundwater monitoring effort must coexist to ensure that shallow aquifers are not contaminiated by this waste disposal method. Potential exists for aquifer contamination as well as contamination of surface waters through runoff. However land application can be considered an environmentally sound disposal alternative when conducted properly. Approximately 100 land application facilities for petroleum refinery waste exist in the United States (USEPA, 1983).

Deep-well injection of wastewater is another alternative that may be employed for disposal of refinery effluent. This disposal alternative, when conducted properly, would relieve any water quality impact to the Sampit River and Winyah Bay that would occur with surface disposal. However improper application of this alternate

disposal method could cause pollution of the groundwater. Requirements of this method include determination of the existence of adequate geologic features for receiving the injected waste, including impermeable layers to separate the injection zone from other usable aquifers and capacity of the injection zone to receive the wastewater volume expected over the life of the refinery. The propensity for vertical fracturing of aquicludes also must be considered since this could provide conduits for wastewater migration up into freshwater aquifers. A groundwater monitoring effort must be initiated to determine if contamination of usable aquifers occurs. While no injecion wells are known to exist in this area, the Atlantic Coastal Plain is generally considered to be a suitable region for deep well injection.

Wastewater recycling within the refinery would serve to reduce the overall volume of freshwater usage and the volume of wastewater discharged to some extent. A number of wastewater sources, however, would not be amenable to recycle. These sources include desalter brine, cooling tower blowdown, boiler blowdown and any intake water treatment brines. Wastewater that is reused would have to be biotreated prior to reuse in most cases (Manning and Snider, 1983). This alternative, therefore, would help to alleviate the impact of surface discharge of wastewater to the Sampit River or Winyah Bay, but unlike land application or deep-well injection, some surface discharge would still exist.

b. Spills. The potential for spills and the ultimate effects of these spills are addressed in Section VII.B.2.b beginning on page VII.B-36a of this report. Spills from oil transport vessels or transfer operations at the receiving dock would not be affected by plant location. However potential for pipeline spills increases with the length of oil pipeline and, therefore, may be greater for the Harmony Plantation site than for other siting alternatives.

B. Myrtle Grove, Georgetown, SC

The Myrtle Grove site is located east of the Harmony Plantation site on the south side of the Sampit River (Figure VII-1). It is an upland site consisting of mixed pine hardwood timber and an area of diked wetlands used for the disposal of Georgetown Harbor dredge spoils.

1. Effects of Plant and Pipeline Construction

Plant construction would cause air and water quality impacts similar to those discussed for the Harmony Plantation location alternative, except that water quality impacts may affect a smaller segment of the Sampit River because the Myrtle Grove site is located downstream. The impact of pipeline construction could be slightly less than at the Harmony site because the Myrtle Grove site is closer to the oil transfer terminal and less excavation would be required for a shorter pipeline.

a. Pipeline Routes. The impact of the alternative pipeline routes to the Myrtle Grove site would be the same as for the Harmony Plantation alternative, except that more excavation would be required for the "Around the Sampit River" routing alternative since the overall distance from the receiving pier would be greater to the Myrtle Grove location than to Harmony Plantation.

2. Effects of Plant Operation

Air and water quality impacts resulting from plant operation would be the same as those discussed for the Harmony Plantation alternative.

a. Wastewater Discharge. The impacts of wastewater discharge on water quality would be the same from the Myrtle Grove site as from the Harmony Plantation site alternative. However the distance from the Myrtle Grove location to a suitable outfall location may be less and hence impacts from outfall piping construction could be less. Additionally this siting location would tend to promote the selection for wastewater outfall location of the lower Sampit River or Winyah Bay, either of which would exhibit higher dilution capability than upstream outfall locations.

b. Spills. The impact of spills would be the same as those discussed for the Harmony Plantation site. The potential for pipeline spills may be less for the Myrtle Grove site if the overall oil pipeline length is less than for the Harmony Plantation site.

C. Charleston, SC

The Charleston alternative site is located on the Cooper River above the Amoco Chemical Plant. Consideration of this site has been terminated by the applicant as a result of air quality standards limitations.

1. Effects of Plant and Pipeline Construction

Details of plant and pipeline construction are not available for this alternative. The impact on Cooper River water quality would probably be similar to the Sampit River impacts described above for the Harmony Plantation siting alternative. Air quality impacts as a result of construction activities would be similar to those discussed for the Harmony Plantation alternative.

2. Effects of Plant Operat on

Impacts to the Cooper River from plant operations would be similar to those described for the Harmony Plantation site and the Sampit River. Ascertaining the potential water quality impact from oil spills in the Cooper River and downstream areas would require further site-specific study. Shipping hazards would vary from those associated with Winyah Bay and the Sampit River. Pollution impacts to sensitive areas in the Cooper River estuary may be less, however, because of the more extensive wetlands that could be impacted in the Winyah Bay estuary.

The quality and concentrations of air emissions resulting from the operation of an oil refinery the same size as the proposed Harmony Plantation refinery would be the same regardless of the location. However the emissions of existing sources in the Charleston area, such as the Amoco Chemical Plant, leave little or no capacity to locate a new major source of air pollutants in that area.

D. Unspecified Sites in South Carolina

Various other sites in South Carolina could be considered for refinery construction, but may not serve the economic needs of the applicant. Specific environmental concerns would need to be determined for each location considered.

1. Effects of Plant and Pipeline Construction

The types of air and water quality impacts from construction in alternate locations would be similar to the impacts associated with construction at Harmony Plantation. The primary water quality impacts would be turbidity increases resulting from runoff from excavated areas. Some hydrocarbon and chemical pollutants also could be introduced through site runoff.

2. Effects of Plant Operation

The characteristics of refinery pollutant discharges would be the same, regardless of the site location. However the impacts of the discharge on ambient water quality would depend upon water circulation, aquatic ecology, sediment and shoreline characteristics of the alternate site being considered. Impacts on ambient air quality would depend upon existing air quality, remaining allowable air quality increments, and meteorological conditions.

The impacts of spills would depend upon the specific site location and the proximity to sensitive areas. However some degradation of water quality would occur as a result of crude oil spills, regardless of the site location.

E. Methods of Handling Oil

Three alternative methods for handling oil for the refinery have been proposed. These methods include transfer at the State Port Authority docks (Pier 31) in Georgetown Harbor, construction of a dock for transfer on the south shore of the Sampit River, and use of an offshore single-point mooring system.

1. Port Authority Dock

Using the Port Authority Dock alternative, oil would be transferred from ship to the existing Port Authority pier (Pier 31) and then through pipelines to the refinery. Pipelines would be routed across the Sampit River by one of the three alternatives discussed in Section VII.A.1.a. (pp. VII-1, VII-3). Impacts to water quality from a crude oil spill at the pier probably would be restricted to the water column and sediments of the lower 4.8 km (three mi) of the Sampit River, Georgetown harbor, and most of Winyah Bay. Impacts would depend upon the volume of spill under consideration and the physical, chemical and biological characteristics of the river and bay at the time of the spill. These characteristics would include the period of the tide, wind and current velocities, freshwater input to the bay, silt loading, the location of the freshwater-saltwater interface, and seasonal variations in water temperature and biological activity. Potential impacts include initial petroleum hydrocarbon pollution of the water column and sediments in the harbor and lower sections of the Sampit River, followed by flushing of some hydrocarbons into Winyah Bay, pollution of sediments in the upper reaches, and dispersion of soluble constituents throughout the water column.

Air emissions associated with marine terminals and in or near ports are generally hydrocarbon emissions from loading and unloading operations. During loading operations hydrocarbon emissi[illegible] can be released as the air space of empty compartments are vented to accomodat[illegible] cargo being loaded. The volume vented could contain hydrocarbon vapors from [illegible]vious cargo and vapors from the cargo being loaded. Unloading operations also can result in hydrocarbon emissions from accidental spills and leaks. Emissions from ballasting are similar to loading emissions. Ballasting is required to ensure proper ship seaworthiness, stability and balance, trim, and propeller immersion.

Tankers in port also emit considerable pollutants from ship boilers which supply power for the maintenance of the ship's systems. The present operating practices, frequency of occurrence, and levels of emissions and emissions controls associated wtih these and other transfer operations are unknown (MITRE Corp., 1981).

2. Construction of Mooring and Pumping Facilities on the South Shore of the Sampit River

This alternative would alleviate the need for a pipeline crossing of the Sampit River. Construction of facilities on the south shore could reduce the impact of increased turbidity and possible release of organic or chemical pollutants that could occur during excavation across the Sampit River. However some increase in turbidity and discharge of pollutants into the Sampit River could result from pier construction on the south shore.

Because of increased construction activity on the south shore, however, the impact on water quality could be greater from this alternative than from the possible alternatives of using the existing Port Authority pier, and either crossing the Sampit River by tunneling beneath the river or suspending the pipeline from the U.S. Highway 17 bridge.

The effects of petroleum hydrocarbon spills and air emissions during transfer operations from the south shore location would be similar to those discussed for the Port Authority Docks, except that the impact to Georgetown Harbor waters and sediments could be less.

3. Single-Point Mooring System

A single-point mooring system would allow offloading of crude oil offshore and transport via pipeline to the proposed refinery. This alternative would eliminate the potential impact of shipping or handling spills on the water quality of the Sampit River and upper Winyah Bay. However oil spills during transfer at the single-point mooring system could impact water quality in the lower portions of Winyah Bay and along Atlantic coastal areas. Construction of the pipeline from the mooring location to the refinery would cause additional impacts on water quality, paticularly increased turbidity during excavation and installation.

With offshore transfer of crude oil, the major chronic source of pollution to the Sampit River and Winyah Bay would be wastewater discharge from the refinery. Therefore the single-point mooring system would only reduce impacts associated with tanker traffic spills in Winyah Bay.

Air emissions during transfer operations whether on shore or at sea would be the same. However the impact of emissions on populated areas would be reduced if the single-point mooring system is used.

F. Larger or Smaller Refineries

1. Larger Refinery

A larger refinery located at Savannah, Georgia, rather than any refinery located in Georgetown, SC, obviously would not affect the air or water quality of the Georgetown area. This would be the same as a "no action" alternative with respect to this area. A larger refinery in Savannah probably would produce an adverse impact on air and water quality in that area and would be the subject of an additional study.

2. Smaller Refinery

Building a smaller refinery at Georgetown could result in less air and water quality degradation than would be expected from the proposed refinery. The amount of pollutants discharged from a refinery is a function, in part, of the volume of crude oil refined. The impacts of spills during shipment, transfer and handling would be the same, regardless of refinery size. However the potential for such an occurrence would decrease with the decrease in the number of port calls made by the oil tankers.

G. Permit Issuance

Issuance of a permit for the proposed plant to discharge wastewaters would result in the water quality impacts discussed in this report.

H. Permit Issuance with Conditions

Some conditions may be applied to the permit that would reduce the impact of wastewater on the water quality of the Sampit River and Winyah Bay. These conditions could include the requirement for further treatment of wastewaters to reduce the level of oil and grease discharged to the receiving waters, as well as selected treatment to reduce the levels of other pollutants that pose a significant threat to water quality.

I. Permit Denial

This no-build alternative would eliminate the future impact of the proposed refinery operations on the air and water quality of the Georgetown area. This alternative would help to alleviate further degradation of the environmental quality of this area.

J. Summary

A comparison of air and water quality impacts for the two primary sites, Harmony Plantation and Myrtle Grove, is presented in Table VII.1. A comparison of water quality impacts for the three methods of handling oil is provided in Table VII.2, and a comparison of disposal alternatives is presented in Table VII.3.

TABLE VII.1

COMPARISON OF AIR AND WATER QUALITY IMPACTS ASSOCIATED WITH THE MAJOR SITING ALTERNATIVES
PROPOSED CRDC REFINERY GEORGETOWN, SOUTH CAROLINA

Activity	Harmony Plantation	Myrtle Grove
Plant Construction	Approximately 40.5 ha (100 ac) of cutover forestland would be converted. Drainage/runoff patterns may be altered, increasing turbidity in the Sampit River during con-struction phase. Runoff of chemicals and hydrocarbons into the Sampit River may result from spills at the con-struction site. Approximately 11.3 km (seven mi) of the Sampit River could be affected, assuming a discharge into the river about 6.4 km (four mi) from the mouth and an additional 4.8 km (three mi) of tidal intrusion. Total flushing time, during dry weather, may range from two to four weeks (Johnson, 1978). Temporary increases in ambient levels of carbon monoxide, particulates, nitrogen oxides and hydrocarbons would be expected in the local area of construction due to exhaust from engines, welding and other construc-tion activities.	Mostly upland site which includes an area of diked wetlands used for disposal of dredge spoils. Potential for alterations to drainage/runoff patterns and Mostly upland site which includes an area of diked wetlands used for disposal of dredge spoils. Potential for alterations to drainage/runoff patterns and increased turbidity in the Sampit River. Potential for some runoff of chemicals or hydrocarbons from the construction site. Approxi-mately eight km (five mi) of the Sampit River could be affected. Total flushing time probably would be somewhat less than two to four weeks. Air quality impacts would similar to those discussed for the Harmony Plantation alternative.
Pipeline Construction - Under Sampit River 1. Trenching	Excavation of a 1.8-m (six-ft) deep trench across 182.9 m (600 ft) of the Sampit River temporarily would increase turbidity in the Sampit River and possibly in upper Winyah Bay Area affected would be approximately eight km (five mi) of the Sampit River. An increase in BOD and chemical pollutants, particularly ammonia, may result from disturbance of bottom sediments during dredging. Greater increases in turbidity and the release of other pollutants may occur if blasting would be required for excavation. Total flushing time should be no more than two to four weeks. Air quality impacts would be similar to those for plant construction.	Same as for Harmony Plantation except pipeline route on south shore would be shorter.

TABLE VII.1
(continued)
COMPARISON OF AIR AND WATER QUALITY IMPACTS ASSOCIATED WITH THE MAJOR SITING ALTERNATIVES
PROPOSED CRDC REFINERY GEORGETOWN, SOUTH CAROLINA

Activity	Harmony Plantation	Myrtle Grove
2. Tunneling	Tunneling under the Sampit River bottom would create little impact to water quality, limited to some turbidity increases due to shore activity. Air quality impacts are similar to those for construction of the plant.	
- Suspension of pipeline from U.S. Highway 17 bridge	Slight increase in turbidity levels in Sampit River due to excavation on the river bank. No disturbance of bottom sediments expected. Air quality impacts are similar to those for construction of the plant.	Same as for Harmony Plantation except pipeline route on south shore would be shorter.
- Around Sampit River	About 36.6 km (24 mi) of pipeline trench would be excavated. Runoff from excavated areas could increase turbidity and pollutant levels in the Sampit River, particularly where the excavation crosses headwater stream tributaries. Air quality impacts are similar to those for construction of the plant.	Same as for Harmony Plantation except pipeline route would be longer on south shore.
<u>Plant Operation</u> - Wastewater discharge	Refinery wastewater discharge would create a chronic input of pollutants into the Sampit River and subsequently Winyah Bay. These pollutants would include oil and grease, ammonia, BOD, phenols, sulfides, heavy metals and various other organic compounds. The location of the wastewater outfall would affect the overall impact of the wastewater on the receiving stream. The most direct discharge from this siting alternative would be an outfall into Turkey or Pennyroyal Creek and ultimately to the Sampit River. This could impact about 9.6 km (six mi) of the Sampit River and a significant impact to the water column and sediments of the creeks would be expected.	Same basic impact as for Harmony Plantation. Downstream siting location would allow shorter distances for discharge piping. Most direct discharge to the Sampit River would be closer to the mouth or into the bay and, hence, probably only about 4.8 km (three mi) of the river would be impacted by wastewater pollutants.

TABLE VII.1
(continued)
COMPARISON OF AIR AND WATER QUALITY IMPACTS ASSOCIATED WITH THE MAJOR SITING ALTERNATIVES
PROPOSED CRDC REFINERY GEORGETOWN, SOUTH CAROLINA

Activity	Harmony Plantation	Myrtle Grove
- Wastewater (con't)	Routing the outfall closer to Winyah Bay would require up to 4.8 km (three mi) or more of pipeline excavation with associated pipeline construction impacts.	
- Spills	Runoff from spills at the site would affect the Sampit River directly causing degradation of quality due to petroleum hydrocarbons in the water column and sediments. Water quality in Winyah Bay also would be affected. Severity would be controlled by amount of spill cleaned up, location of spill and characteristics of the bay at the time of the spill.	Same as for Harmony Plantation except less of the Sampit River would be affected by direct ruroff of spills at the site.
- Air Quality	The air qualtiy analysis performed has indicated that maximum impacts from the proposed facility may cause violations to the hydrocarbon and ozone ambient air quality standards. The analysis has also shown under worst case meteorological conditions that sulfur dioxide impacts from the facility may consume and violate the remaining allowable sulfur dioxide increment. However, an air quality analysis based on specific process emissions and final design must show that all air quality standards will be met and no remaining allowable increment will be exceeded before the required air quality permit can be obtained from DHEC.	Air quality maximum impact would be the same as for the Harmony Plantation. However, as this site is closer to Georgetown, short-term impacts on Georgetown may be slightly higher.

TABLE VII.2

COMPARISON OF OIL TRANSFER HANDLING ALTERNATIVES
PROPOSED CRDC REFINERY
GEORGETOWN, SOUTH CAROLINA

Port Authority Dock	South Shore of Sampit River	Single-Point Mooring System
Oil transferred from ship to existing Port Authority docks. Pipeline transfer over, under or around Sampit River to refinery location.	Construction of dock and pumping facilities required. Short-term water quality impacts may occur from this construction. These include increased turbidity in lower Sampit River and possibly upper Winyah Bay and runoff of petroleum hydrocarbons and other construction pollutants.	Construction of offshore system temporarily would increase turbidity in local area but should not impact Sampit River or Winyah Bay.
Impacts would be from spilled oil at transfer site or from pipeline. Decrease in water quality due to presence of crude oil components in water column and sediments would occur. Handling spills generally would affect lower 4.8 to 6.4 km (three to four mi) of Sampit River, Georgetown harbor and much of Winhah Bay, depending upon severity of spill and physical characteristics of bay at time of spill.	Water quality impacts due to river excavation for pipeline crossing no longer would need to be considered.	Oil spill from handling may be more likely to occur and would have a greater impact on coastal areas, possibly including North Inlet. Impact to Winyah Bay probably would be limited to lower areas.
Pipeline spill may affect greater portions of the river, depending upon location of spill.	Oil spill impacts same as for Port Authority Dock alternative. Shorter pipeline should decrease potential for pipeline spill.	Increased length of pipeline would increase potential for a pipeline spill. Impact from such a spill would be affected by location and size of leak or breach.

TABLE VII.3

COMPARISON OF WASTEWATER DISPOSAL ALTERNATIVES

Alternative	Environmental Considerations	Other Considerations
1. Discharge to Turkey or Pennyroyal Creek	Low dilution capacity and low flushing capability would probably cause pollutant concentration in creek waters and sediments. Some disruption of runoff patterns and other hydrologic effects from pipe installation. Some impacts to water quality in Sampit River and Winyah Bay by pollutants flushed from the creeks.	Most direct discharge location to Harmony Plantation site. Low construction cost, easy maintenance.
2. Discharge directly to Sampit River	Overall impact may vary with location of outfall. General increase in pollutant levels in water column and sediments of Sampit River and Winyah Bay. Possible concentration of such pollutants in upper river and bordering wetlands. Dredging of wetlands for outfall piping may be required.	Greater construction cost, varying with location of outfall and choice of siting alternative.
3. Discharge directly to Winyah Bay	Water quality impact in vicinity of the outfall. Better dilution capacity than creek or river discharge alternative. More extensive dredging and excavation would probably be required for installation of outfall piping. Possible requirement for dredging in Winyah Bay in vicinity of outfall location.	Higher construction cost for Harmony Plantation siting alternative than for discharge to creeks or river. Lesser cost for Myrtle Grove siting.

TABLE VII.3
(continued)
COMPARISON OF WASTEWATER DISPOSAL ALTERNATIVES

Alternative	Environmental Considerations	Other Considerations
4. Discharge directly to Atlantic Ocean	Water quality impact in vicinity of outfall. High potential for dilution. Low potential for impact to Winyah Bay waters during operation. Extensive overland and wetland excavation, approximately 24 km (15 mi), would be required for outfall piping.	High cost for outfall system.
5. Land application	Possible runoff of pollutants to surface waters, but overall less impact than surface discharge. Possible infiltration of pollutants to water table aquifer. Some impacts from construction of the system could be expected.	Higher cost of construction than surface discharges. Higher operational and maintenance costs. Requirement for suitable land areas.
6. Deep-well injection	Possible contamination of groundwater through abandoned wells, injection well failure or fractures through confining layer. Little if any impact to surface waters.	Groundwater monitoring and mechanical integrity testing required to safeguard the operation. Higher construction and maintenance expense than surface discharge alternatives.
7. Wastewater recirculation	Some reduction in overall water consumption. Some reduction in volume of wastewater and concentration of pollutants discharged.	Extensive treatment required for reuse. Must be considered in initial plant design. Higher initial cost than most other alternatives. Complete reuse of all wastewaters not reasonable.

A. Air Quality

1. Effects of Plant and Pipeline Construction

a. Air Emissions Impacts. Construction activities may affect the air quality within the Georgetown area. The use and operation of construction equipment and trucks transporting excavated earth and construction materials contribute to levels of carbon monoxide, particulates, nitrogen oxides, and hydrocarbons. Construction operations such as clearing of rights-of-way, welding, painting and paving also contribute to air quality impacts.

Due to the lack of specific information concerning construction scheduling, numbers of construction vehicles, and construction details, the air quality impacts could not be quantified, but it is reasonabe to assume that impacts will be localized and of short duration.

b. Mitigative Methods. A number of mitigative measures to reduce the air quality impact during construction can be implemented. Normal construction procedures require dust control, such as the use of dust palliatives, truck tire washing stations, and wetting exposed soils. This type of mitigation is generally inexpensive and can reduce fugitive particulates by substantial amounts.

Construction scheduling can be adjusted to minimize the number of construction vehicles in use. Scheduling can also coordinate peak project related transportation with off-peak traffic hours of local transportation. These types of measures can reduce the emissions impacts from construction vehicles.

2. Effects of Plant Operations

a. Emissions Identification

(1) Unit Operations and Controls. A block flow diagram of the proposed refinery process is shown on Figure VII. A-1. The process shown in the figure and described below is the latest in a series of process schemes considered for the proposed facility.

In process Scheme 6 (Cathcart, 1982), "the atmospheric distillation of the crude and coker distillation are combined in a single tower. The bottom steam from this tower will contain both virgin atmospheric reduced crude and coker recycle, and is charged to the delayed coker. About 1100 tons per day of high sulfur (3.5 to 5.5 percent) coke is produced. Cracked vapors from the coke drum return to the distillation tower and, along with the virgin distillates, are separated into appropriate boiling range cuts. A small gas oil stream is sold without further treatment. Naphtha, kerosene and diesel cuts are hydrogen treated and blended into jet fuel (JP-4) and diesel fuel. A hydrogen plant is required to supply hydrogen for the hydrogen treating unit.

"Light ends from the crude/coking unit and from the hydrotreater are separated in a vapor recovery unit to yield a propane-butane liquid stream and fuel gas. The liquid and gas streams are treated to remove sulfur compounds. The liquid stream is charged to a catalytic polymerization unit to produce polymer gasoline, butane, and some additional fuel gas."

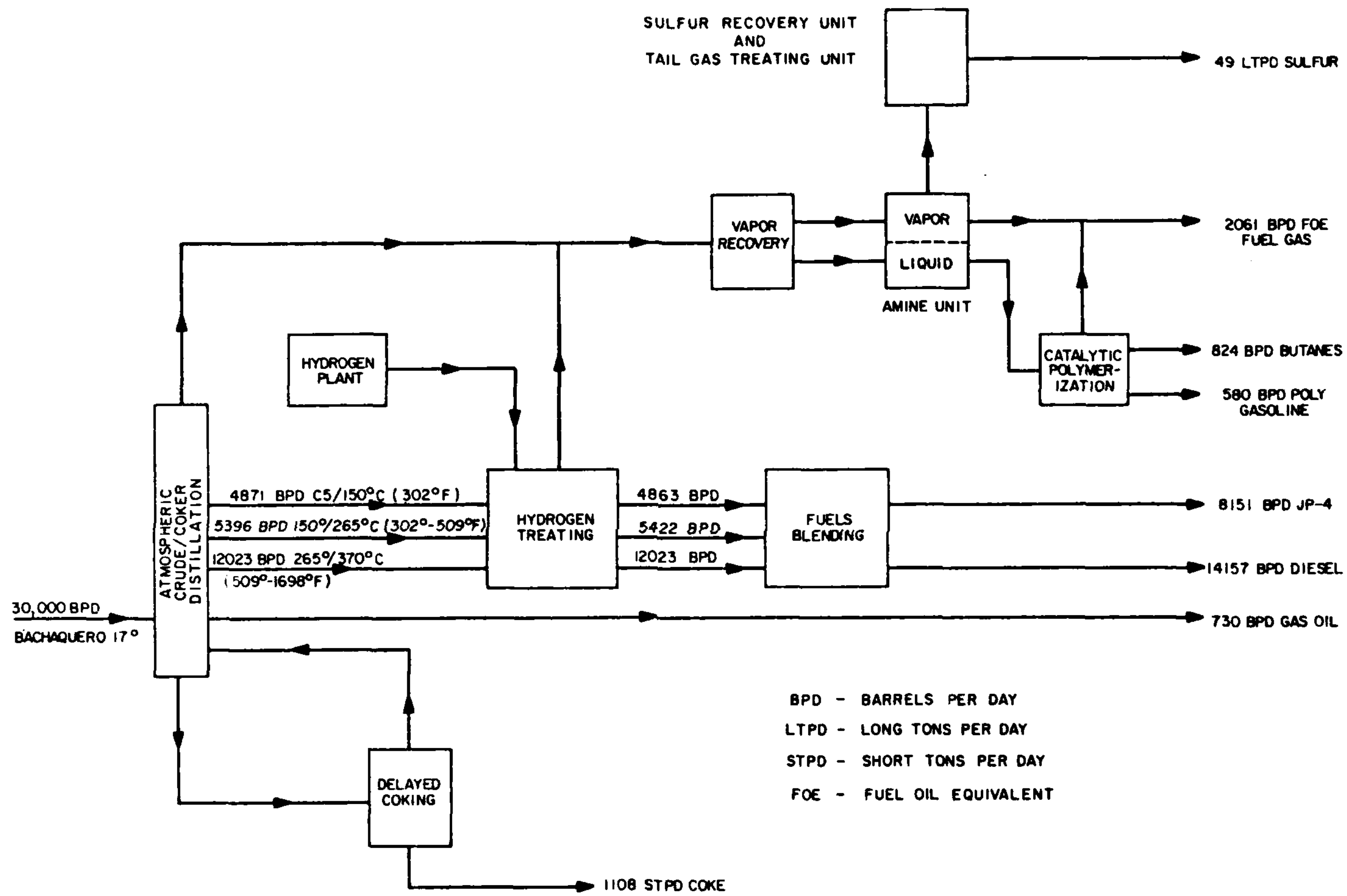


Figure VII.A-1. Proposed process schematic CRDC Georgetown Refinery.
Source: Cathcart, 1982.

The refinery will be designed to process sour crudes such as the Bachaquero (Venezuela) Crude (Cathcart, 1983a). Properties of the Bachaquero Crude, nominally 17°API, and potential products are presented in Table VII.A-1. The removal of sulfur from crude oil during the production of refinery products is a major task performed by refining processes. Combustion of sulfur-containing petroleum products leads to the formation of sulfur dioxide (SO_2), an objectionable pollutant. Sulfur in crude oil occurs as malodorous hydrogen sulfide (H_2S) and as thiols (mercaptans), thiophenes, sulfides, and polysulfides. The nature and concentration of sulfur compounds varies with each crude oil.

It should be noted that Carolina Refining and Distributing Company (CRDC) does not presently own the property or have an option on the property where the proposed refinery would be located. Because of this, the exact location of the property boundaries is not known. Also, the building dimensions, plot plan, and construction details have not been detailed to date. However, the proposed height, diameter and emission stream velocity and temperature have been estimated for seven air emission sources (Taggart, 1984).

From information made available through the air permit application and supporting data submitted to the South Carolina Department of Health of Environmental Control, the proposed major refinery unit processes and appurtentant operations are described below.

(a) Crude Desalting. Inorganic salts, water, suspended solids, and certain water soluble compounds must be removed from crude oils to prevent equipment fouling, corrosion, and catalyst poisoning in refinery processing units. Crude desalting is essentially a solvent extraction process using water as the extracting medium (MITRE Corp., 1981).

(b) Crude Oil Fractionation. Crude oil is distilled using a fractionation unit (Heating and Flashing Unit) to separate it into fuel gas and gaseous sulfur compounds, middle distillates including liquid fuels (gasoline) and naphtha, and a final bottom residual. Crude oil consists of a mixture of hydrocarbon compounds including paraffinic, naphthenic, and aromatic hydrocarbons plus small amounts of impurities including sulfur, nitrogen, oxygen, and metals. Refinery separation processes separate these crude oil constituents into common-boiling-point fractions. Distillation is essentially a closed process in terms of atmospheric releases. Fugitive hydrocarbon emissions and process heaters are the major sources of atmospheric emissions (MITRE Corp., 1981).

(c) Hydrogen Treating. Hydrodesulfurization involves the catalytic (nickel-moly) combination of hydrogen with feedstock hydrocarbons. In most processes, the feedstock is mixed with hydrogen, heated, and charged under pressure to catalytic reactor units. Hydrotreating causes sulfur-bearing compounds to form hydrogen sulfide and nitrogen-bearing compounds to form ammonia. Aproximately 90 percent of the sulfur and nitrogen are removed from the feedstock (MITRE Corp., July 1981). Light ends from the hydrotreater are separated in a vapor recovery unit to yield a propane-butane liquid stream and fuel gas (Cathcart, 1982).

(d) Coker. The bottoms from the crude oil fractionation unit are subjected to a coking process. Coking is a thermal cracking process used to convert low residual fuel oil to lighter products and petroleum coke. Delayed coking is the most widely used process today. In the delayed coking process, the heated residual oil is combined with recycle products from the coke drum and rapidly heated in the coking heater. Steam injection is used to control the resi-

TABLE VII.A-1

CAROLINA REFINING-GEORGETOWN REFINERY
CRUDE AND PRODUCT SLATE

Crude Oil: Proposal is for 30,000 BPD of Bachaquero (Venezuela) Crude, nominally 17° API having properties essentially as follows:

Gravity, °API			-	16.8
Sulfur, Wt. %			-	2.4
Viscosity, SVS at 100°F			-	1,362
Pour Point, °F			-	-10
RVP, psi			-	1.6
Yield, 0° (IVT) -82°F, vol. %			-	0.80
Light Naphtha	-	18/93 °C (82/200°F), Vol. %	-	2.44
Heavy Naphtha	-	93/149°C (200/300°F), Vol. %	-	3.54
Naptha	-	149/177°C (300/350°F), Vol. %	-	1.81
Kerosene	-	177/205°C (350/400°F), Vol. %	-	2.11
Gas Oil	-	205/260°C,(400/500°F), Vol. %	-	6.37
Gas Oil	-	260/288°C (500/550°F), Vol. %	-	3.93
Gas Oil	-	288/343°C (550/650°F), Vol. %	-	8.95
Residue	-	343° + °C (650° + °F)	-	70.24

Products are as follows:

Fuel Gas	-	2,061 BPD (Fuel Oil Equivalent)
Butanes	-	824 BPD
Poly Gasoline	-	580 BPD
JP4	-	8,151 BPD
Diesel	-	14,157 BPD
Gas Oil	-	730 BPD
Coke	-	1,108 STPD
Sulfur	-	49 LTPD

Oil and Gas Journal, Oct. 24, 1983.

Cathcart, 1983

dence time in the heater. The vapor-liquid feed leaves the heater, passing into a coke drum where, with controlled residence time, pressure, and temperature, it is cracked to form coke and vapors. During the coking cycle, the off gases will go to the fractionator to be processed.

Particulate emissions from delayed coking operations are potentially significant. These emissions are associated with removing the coke from the coke drum and subsequent handling and venting the coke drum prior to coke removal. Particulate from blowdown and steam-out of the drum will be controlled by a coker blowdown system. Dusting of coke product will be limited by handling it wet within a totally enclosed building (Davis and Floyd Engineers, Inc., 1978b; USEPA, 1977).

(e) Catalytic Polymerization (Reforming). Catalytic reforming is primarily used to increase the octane rating or antiknock qualities of naphtha from the crude oil fractionation unit. Catalytic reforming also causes other reactions such as paraffin hydrocracking, paraffin dehydrocyclization, and paraffin isomerization to occur. Hydrogen from dehydrogenation reactions is a major by-product of catalytic reforming. The hydrogen is cryogenically purified and then fed back to the reformer and used in hydrotreatment of naphtha and kerosene.

Feedstocks to the reforming unit are desulfurized naphthas and naphthene-rich fractions. Removal of sulfur, nitrogen, arsenic and other metals from the feedstock is required to prevent poisoning of the platinum catalyst. During the process, the feedstock and recycled gases are heated and passed through a series of catalytic reactors. The reactor output is separated into liquid and gas streams; the gases are compressed for recycling and liquids are stabilized. This is a closed system process. Slight atmospheric emissions may occur during catalytic regeneration, mostly as carbon monoxide.

(f) Tail Gas Treating Unit and Sulfur Recovery Unit. The Pritchard Claus process produces commercial elemental sulfur from hydrogen sulfide (H_2S) removed from sulfur-bearing gas streams. Major process items include an acid gas furnace, waste heat boiler followed by a sulfur condenser, and three converters. In this process, one-third of the H_2S in the gas stream is burned to form sulfur dioxide (SO_2); the resulting SO_2 reacts with the balance of the H_2S to form sulfur and water vapor. The sulfur is consensed and recovered from the vapor stream as a liquid. The use of boiler feedwater as the cooling medium in the sulfur condensers allows heat recovery for maximum high pressure steam generation.

The emissions from the Claus Unit will flow into a Stretford Unit for additional sulfur removal. The Stretford process is a regenerative oxidation/reduction process that uses aerial oxygen to produce elemental sulfur. The emissions from the Stretford Unit will be incinerated, converting H_2S to SO_2.

The overall sulfur recovery on the sulfur recovery units is 99.9 percent. The SO_2 content of the resulting emissions will be less than 0.025 percent by volume of SO_2 at zero percent oxygen on a dry basis. The unit will meet NSPS requirements for Petroleum Refinery Claus Sulfur Recovery Plants, as published in the Federal Register, March 15, 1978, 40 CFR Part 60, Section 60.104(a)(2)(i). The exhaust will be continuously monitored and concentrations of SO_2 recorded (Cathcart, 1983b; Davis and Floyd Engineers, Inc., 1978b).

(g) Process Heaters. On-site power will be generated by a gas turbine generator fired with process fuel gas. Unit process heaters located at various unit processes will use gas turbine generator exhaust as a primary heat source. As additional heat or additional control of heat as needed may be required, supplemental fuel gas will be supplied to the unit heaters. Process heaters are used throughout the refinery process to heat feedstocks to reaction temperatures and for distillation. In addition, two natural gas fired boilers will be on standby for start-up and emergency operation. It is estimated that the average annual usage of these boilers would be approximately 200 hours. Air emissions will be minor and would meet applicable South Carolina DHEC standards for emissions from fuel burning operations.

The SO_2 emissions from the gas turbine will be controlled by limiting the sulfur content of the fuel gas. Nitrogen oxides (NO_x) emissions will be controlled by injection of water into the combustion reaction to reduce peak flame temperatures. These controls will enable the turbine emissions to meet NSPS requirements for stationary gas turbines, published October 3, 1977, in the Federal Register, 40 CFR Part 60 (Davis and Floyd Engineers, Inc., 1978b).

(h) Catalyst Regeneration. Platinum catalyst in the catalytic reformer and nickel-moly catalyst in the hydrodesulfurization unit will be regenerated on site. The platinum catalyst will be regenerated every six months using steam and air. The nickel-moly catalyst will be regenerated approximately once a year. Off gases from these operations will be to the atmosphere. Fines resulting from the regeneration of the catalysts will be landfilled (Davis and Floyd Engineers, Inc., 1978b).

(i) Vapor Recovery System. Vapor emissions from crude oil storage tanks, petroleum distillate storage tanks, and bulk leading/unleading facilities will be collected in a common piping system connected to a tank with a floating roof. Collected vapors will be compressed and processed as fuel gas. Hydrocarbon emissions from these sources will be reduced by approximately 95 percent using this system, resulting in an emission rate of approximately 12.7 kg/hr (28 lb/hr; Davis and Floyd Engineers, Inc., 1978b).

(j) Pressure Relief and Flare Systems. Pressure relief and safety outlets are required to relieve potentially damaging pressures within the processing equipment, especially during start-ups, shut-downs, and emergency situations. Environmental and safety concerns require a closed collection system and disposal of collected gases through combustion in a flare. An emergency cokeless flare is proposed for use only during emergencies or process upsets. The proposed flare will be ignited electronically and manually controlled, with an estimated capacity of 13,608 kg/hr (30,000 lb/hr) or 600 x 10^6 BTU/hr (Davis and Floyd Engineers, Inc., 1978b).

b. Emissions Characterizations. While emissions vary greatly among refineries, most available information and data regarding air pollutants concern regulated refinery pollutants, primarily hydrogen sulfide, sulfur oxides, carbon monoxide, particulates, nitrogen oxides, and volatile organic compounds (hydrocarbons). Other emissions such as aldehydes, ammonia, hydrogen cyanide, carbon dioxide, hydrogen chloride and odors are also of some concern. Major air pollution sources within the refinery are:

- Combustion sources - process heaters and boilers;

- Process units - coking units, catalytic cracking, catalyst regeneration, and incinerators or flares;

- Storage and transfer activities; and

- Wastewater and air pollution control and treatment systems.

Air emissions occur from many specific sources. Air pollution control systems are usually associated with specific process units and are designed to remove or modify specific pollutants. The chemical content and disposition of refinery air emissions are not well documented due to the multiple sources within the refinery, the three-dimensional dispersion of these pollutants, and selective monitoring requirements (MITRE Corp., 1981).

A review of potential emissions from the CRDC follows:

(1) Hydrogen Sulfide. H_2S is an odorous, toxic gas associated with a number of sources within the refinery. It is potentially dangerous to workers due to its greater than air density and its tendency to paralyze the olfactory nerves, making strong concentrations undetectable by odor. Sources within the refinery include: vaporization of crude oil and raw distillates; decomposition of sulfur compounds and interaction of free sulfur with hydrocarbons; gases driven off during distillation, which may contain up to 80 percent hydrogen sulfide; evaporation from aqueous solutions, such as settled water in crude and sour distillate storage tanks; and anaerobic bacterial decomposition of sulfur-containing organic materials in refinery sewer systems (MITRE Corp., 1981).

The H_2S concentration in the fuel gas has been estimated (Davis and Floyd Engineers, Inc., 1978b) at less than 0.2 grams per cubic meter (1 GR./DSCF). A monitor will be placed on the fuel gas stream to continuously monitor the H_2S concentration of the fuel gas. The monitor chosen will meet all applicable USEPA requirements.

(2) Sulfur Dioxide. Sulfur oxides, mostly SO_2 and some sulfur trioxide (SO_3), are emitted from refineries in quantities directly related to the sulfur content of the crude oils being processed. Potentially hazardous concentrations of SO_2, if uncontrolled, could result from combustion of fuels containing sulfur compounds, vent gases from the Claus - Stretford tail gas treating system and flaring of vent gases, including breathing of tanks and system blowdowns.

The emissions of SO_2 are to be controlled to less than 45.3 metric tons/year (50 tons/year) by reducing fuel gas sulfur to 20 ppm, by appropriate vapor treatment from free breathing tanks containing sour materials; and by using the very efficient Claus tail gas treating processes (Cathcart, 1983b).

(3) Carbon Monoxide. The principal source of CO is combustion processes and results from the incomplete combustion of fuels. CO emissions from the CRDC have been estimated to be below 90.7 metric tons/year (100 tons/year). Estimates were based on emissions of approximately 66.6 metric tons/year (73.4 tons/year) from power boilers fired with natural gas, and flare emissions of approximately 21 metric tons/year (23.2 tons/year). It is anticipated that CO emissions can be reduced by reducing combustion requirements by maximizing conservation; incineration instead of flaring, or vapor recovery; and proper design of combustion equipment (Cathcart, 1983b).

(4) Total Suspended Particulates. Fuel gas combustion, delayed coking and catalyst regeneration are the principal sources of particulate matter. However, data regarding amounts, constituents, and sizes of refinery-generated particles are unavailable. With the exception of catalytic fines, it can be assumed that most particulates are formed from organic compounds undergoing incomplete combustion. Various amounts of potentially hazardous PAHs (polynuclear aromatic hydrocarbons), metal oxides aldehydes, and other products of incomplete combustion may be associated with particulate matter (MITRE Corp., 1981).

TSP emissions from the refinery have been estimated at 90.7 metric tons/year (100 tons/year; Cathcart, 1983b). Fuel gas combustion is a potential source for 19.6 to 58.8 metric tons/year (21.6 to 64.8 tons/year) of TSP. Recent tests on gas burners indicate emissions of about 29.5 metric tons/year (32.5 tons/year), a portion of which is ambient dust recycled by furnace combustion air.

No data have been published on TSP from delayed coking. However, it is expected that blowdown and steam-out of the coking drums will be controlled by a coker blowdown system that will virtually eliminate particulate carryover. TSP and fugitive dust from coke handling will be limited by handling it wet and minimizing on-site storage. Other fugitive particulate sources include an estimated 900 gms/hour (2 lbs/hour) during annual or semi-annual regeneration of catalysts.

(5) Nitrogen Oxides. Emissions of NO_x result from combustion processes and catalyst regeneration. NO_x emissions will require the application of Best Available Control Technology (BACT) to minimize emissions. Emissions control will include proper design of combustion equipment, reduction of available oxygen by minimizing excess air in the combustion process, and reduction of peak-flame temperature. Process heaters will have two-stage combustion to reduce the peak-flame temperature and burner configurations will be designed to reduce NO_x emissions. Total emissions from the facility, including NO_x emissions, will be further minimized with the utilization of the exhaust gas from the gas turbine to supplement the heat produced in the process heaters. The efficient use of this energy will result in lower emission rates than if all of the heat were produced by fuel combustion (Davis and Floyd Engineers, Inc., 1978c).

NO_x emissions are estimated at 393 metric tons/year (433 tons/year) from combustion processes and an additional 92.5 metric tons/year (102 tons/year) from the flare (Cathcart, 1983b). Allowing 58 metric tons/year (64 tons/year) of NO_x for the boiler plant, heaters can be taken as accounting for 334.9 metric tons/year (369 tons/year) NO_x (Taggart, 1984).

(6) Volatile Organic Compounds. Refineries may release considerable quantities of airborne organic compounds, mostly lightweight volatile hydrocarbons. These hydrocarbons range in size and complexity from the simple alkanes to the polynuclear aromatic hydrocarbons (PAHs) and may contain elements other than carbon and hydrogen. The composition of hydrocarbon emissions from a refinery can be expected to be a composite of all the volatile substances in the crude oil, refinery intermediates, and final products. Sources of these emissions include storage losses, loading and unloading losses, various fugitive sources, cooling towers, API separators, process drains, and combustion processes. As shown on Table VII.A-2, uncontrolled VOC emission estimates from identified sources are estimated to be 4,121.4 metric tons/year (4,540 tons/year). A vapor recovery system for storage and loading/unloading facilities would reduce hydrocarbon emissions from these sources.

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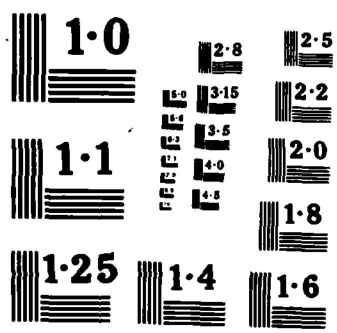
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TABLE VII.A-2

UNCONTROLLED VOC EMISSIONS

Source	Emission factor[1]	Emissions Metric tons/year	(tons/year)
Process drains	31.7 gm/hr (0.07 lb/hr) source -100 source	27.2	(30)
Pump seals	113.3 gm/hr (0.25 lb/hr) source - 100 sources	98	(108)
Compressors	635 gm/hr (1.4 lb/hr) source - 10 sources	54.4	(60)
Valves	26.7 gm/hr (0.059 lb/hr) source -2000 sources	462.9	(510)
Separators	2,268 gm/3785 l (5 lb/1000 gal) waste water	1066.6	(1175)
Cooling towers	2,722 gm/3,785,000 l (6 lb/1,000,000 gal) C.W.	61.7	(68)
Loading:			
Ballasting	272 gm/3,785 l (0.6 lb/1,000 gal)	123.4	(136)
Gasoline	3,629 gm/3,785 l (8 lb/1000 gal)	450.2	(496)
Kerosene	14 gm/3,785 l (0.03 lb/1,000 gal)	2.7	(3)
Storage:			
Crude		752.5	(829)
Diesel		45.3	(50)
Gasoline		975.8	(1075)
		4121.4	(4540)

SOURCE: Cathcart, 1983b

(1) Compilation of Air Pollutant Emission Factors (USEPA, 1977)

The vapor recovery system would consist of a header system connected to a tank with a floating roof. When the vapor pressure is reached, the vapors would be compressed and processed as fuel gas. Hydrocarbon emissions from these sources would be reduced by approximately 95 percent using this system, resulting in a combined controlled emission rate from these sources of 117.5 metric tons/year (129 tons/year) (Davis and Floyd Engineers, Inc., 1978b). Adding this reduced emission rate for storage and loading/unloading facilities to emission rates for the other VOC sources given in Table VII.A-2 gives a reduction of total estimated uncontrolled VOC emissions from 4,121.4 to 1,888.2 metric tons/year (4,540 to 2,080 tons/year).

Best Available Control Technology for hydrocarbons are to be applied to control plant hydrocarbon emissions (Davis & Floyd Engineers, Inc., 1978d). Technologies involved in controlling VOC emissions include closed drain and vent systems, monitoring of cooling towers, floating roof crude oil tanks, and a strict preventative maintenance program (Cathcart, 1983b).

(7) Aldehydes. Aldehydes, including formaldehyde, result from incomplete oxidation of hydrocarbons and may be found in emissions from the various combustion sources in the facility.

(8) Ammonia. Emissions of ammonia may occur from alkaline washing solutions, acid neutralizing, and as a refrigerant. Some ammonia may also be released during catalytic cracking.

(9) Hydrogen Cyanide. During catalytic cracking catalyst regeneration, hydrogen cyanide, a highly toxic gas, can usually be found in the exhausted hot gases (MITRE Corp., 1981).

(10) Thiols. Thiol or mercaptan compounds are some of the most prevalent malodorous gases released from refineries. Thiols are present in crude oils and may be released from fractionation and cracking units (MITRE Corp., 1981).

(11) Phenolic Compounds. Phenolic compounds are present in large quantities in cracked distillates and in some crudes. The presence of thiol odors, even in small concentrations, severely aggravates the obnoxious odors of phenolic compounds.

In summation, it must be noted that air emissions may only be generally characterized in the absence of specific process design parameters. It is possible to design process unit equipment to minimize emissions and to further eliminate or restrict emissions through operating procedures and strict preventative maintenance programs. These should be an important part of the CRDC emissions mitigation program. Other controls should be designed around the use of Best Available Control Technology and the latest proven methods for controlling environmental impacts.

A summary of potential emissions estimates by Cathcart (1983b) are shown below:

Pollutant	Metric tons/year (Tons/year)
SO_2	45.4 (50)
TSP	90.7 (100)
CO	90.7 (100)
NO_x	485.6 (535)
VOC	4121.4 (4540)

Uncontrolled VOC emissions will be reduced by approximately 95 percent (to an estimated 1888.2 metric tons/year [2,080 tons/year] by the vapor recovery system (Davis and Floyd Engineers, Inc., 1978b).

c. How Emissions Change Ambient Conditions

(1) Air Quality Dispersion Modeling. Since initiation of planning for the proposed project, computer modeling of the Georgetown area air quality has been conducted by a number of agencies. Three studies relevant to the CRDC Georgetown project are summarized in this section.

(a) South Carolina Department of Health and Environmental Control, Pre-Construction Review. On August 3, 1978, the Carolina Refining and Distributing Company (CRDC) submitted an application to construct an oil refinery near Georgetown, South Carolina. The application, prepared by Davis and Floyd, Inc., Consulting Engineers of Greenwood, South Carolina, presented two site location alternatives and a number of pipeline installation alternatives for the transport of crude and finished product between the proposed facility and the existing port in Georgetown. The application also described proposed process units and estimated air emissions.

On March 27, 1979, the Bureau of Air Quality Control of the South Carolina Department of Health and Environmental Control, hereafter referred to as the Bureau, prepared a Pre-Construction Review and Preliminary Determination for the proposed facility. The Bureau determined that the facility would be a "Major Stationary Source" as defined by the June 19, 1978 PSD regulations. The PSD regulations require that major sources be reviewed to determine if requirements of Best Available Control Technology, ambient air quality limitations, ambient air monitoring, and additional impact analysis are to be met.

The Bureau estimated the air quality impacts to the Cape Romain Wilderness area (a Class I air quality area) and for the area around the Amoco Corporation plant in Berkely County (Class II area with SO_2 increment violations). The CRSTER model was used with one year of Charleston meteorological data and emission source information supplied in the process permit application. The results of the South Carolina DHEC modeling in terms of increments of sulfur dioxide (SO_2) levels at the refinery at ground level is presented below:

Cape Romain Allowable increment ($\mu g\ SO_2/m^3$)	Previously Allotted increment ($\mu g\ SO_2/m^3$)	Carolina Refining Predicted increment ($\mu g\ SO_2/m^3$)
Annual avg. 2	0.2	0.01
24-hr. avg. 5	3.9	0.2
3-hr. avg. 25	19.7	1.3

μg - micrograms

m^3 - cubic meter

The Bureau determined that the predicted impact from the proposed plant would not violate the SO_2 allowable increments at Cape Romain or have a significant impact on the Class II area around the Amoco plant. It was also determined that no further analyses of the impact on the PSD increments were required. In accordance with PSD regulations, an impact analysis on the TSP non-attainment area of Georgetown was not required because the potential TSP emissions were less than 90.7 metric tons (100 tons) per year. Further, ambient air quality monitoring was not required, primarily because the completed application was submitted before August 7, 1978. The Bureau also predicted that the NAAQS for any criteria pollutants would not be violated and determined that the impacts on visibility, soils, and vegetation as a result of growth associated with the plant would be minimal.

The preliminary determination was that, from the standpoint of air quality, the facility could be constructed if conditions, based on emission rate limitations and the submittal of specific design data, were met. The combined emissions rates from all emission points at the plant were not to exceed the following:

Total Emissions From plant	Emissions gm/hr(lb/hr)	Emissions gm/day(lb/day)	Emissions metric tons/yr(tons/yr)
Particulate Matter (TSP)	4,899 (10.8)	117,027 (258)	42.7 (47.1)
Sulfur Dioxide (SO_2)	1,633 (3.6)	39,009 (86)	14.2 (15.7)
Nitrogen Oxides (NO_x)	56,699 (125)	1,363,045 (3005)	496.5 (547)
Carbon Monoxide (CO)	79 (.175)	7,983 (17.6)	2.9 (3.2)
Hydrocarbons (Hc)	6,123 (13.5)	146,964 (324)	53.5 (59)

After public notice, hearing, and review of received comments, the Bureau made a final determination on July 17, 1979, that the plant could be constructed if certain conditions were met. Since construction of the facility did not commence within 18 months of the date permitted, an extension was granted for an additional 18 months. Both the permit and the extension expired on July 17, 1982.

(b) South Carolina Coastal Council, Evaluation of Environmental Assessment Documents for a proposed refinery. In June of 1981, a of report was prepared for the South Carolina Coastal Council that evaluated a number of documents submitted to the Council by the CRDC. The report assisted in determining if the proposed refinery installation was consistent with the South Carolina Coastal Management Program. The air quality section of the evaluation discussed deficiencies in the refinery submittals concerning air quality impacts and stated the need for further analysis. The analysis presented in the report is summarized below.

A computer program was used to solve the Gaussion Plume equations for ground level estimates of pollutant concentrations. Concentrations of SO_2, TSP, CO, HC, and NO_x that would be emitted by the proposed CRDC refinery were calculated for various locations in Georgetown where DHEC has monitoring stations. Also estimated for these locations were the pollutant impacts from existing sources in the Georgetown area. The analysis concluded "that the proposed refinery would not be a factor in attempts to attain the particulate standard in Georgetown nor would it consume more than a percent or so of the allowable PSD increment in the Georgetown area" South Carolina Coastal Council, 1981; Bruce J. Muga and Associates and Wilber Smith and Associates, 1981). Refinery emission rates and source data used in the computer program were based on the allowable emissions set in the July 1978 DHEC permit and modeling. Modeling inputs used for existing sources were also obtained from DHEC.

(c) South Carolina State Ports Authority, Georgetown Port and Industrial Development Study. Davis and Floyd Engineers and Arthur A. Little, Inc. prepared a study for the South Carolina State Ports Authority to identify various opportunities for increasing port utilization and developing Georgetown County's industrial base while maintaining the present environmental quality.

As part of the study for the South Carolina State Ports Authority, an Air Quality Evaluation (Appendix C) was prepared. It was to determine the effects of existing industries on the Georgetown area air quality and to determine the feasibility of permitting the location of new industries in the area. The MPTER air dispersion computer model was used to determine the impacts of emissions on air quality.

The Carolina Refining and Distributing Company was modeled as an existing source due to the existence of an air permit to construct the facility. The report states "As a result of preliminary modeling completed, it has been concluded that there is an excess of 100 percent of the allowable SO_2 increment remaining in the Class II area immediately surrounding Georgetown." The report also states for the Class I area of Cape Romain, "Modeling indicates that approximately 88 percent of the allowable 24-hour average SO_2 increment has been consumed. In addition, approximately 86 percent of the 3-hour average SO_2 increment for the Class I area has been consumed," also, "the model predicts that there will be a decrease in the annual average SO_2 concentrations resulting in an allowable SO_2 increment in excess of 2 micrograms per cubic meter allowed beyond baseline values."

An analysis of the air quality impact on the Cape Romain Class I area was conducted using potential emissions from an assumed new source (equivalent to a paper mill) located at various sites in Georgetown County. Emissions from one of the new source locations resulted in a violation to a Class I SO_2 increment.

The report sponsored by the South Carolina State Ports Authority concluded that new sources could locate in the Georgetown area, however, the location of the source must be chosen with care in order to avoid violations to PSD allowable increments.

(d) Conclusions. Although the air quality analyses from the three reports discussed in this section focused on different aspects of the impact from the proposed CRDC refinery, the general consensus was that the refinery would not violate existing air quality standards or regulations.

All air quality modeling conducted to date for the emissions from the proposed CRDC refinery has been based on the allowable emissions as permitted on July 17, 1979. As stated previously, that permit has expired. The CRDC will be required to apply for a new permit before the facility could be built.

It can be expected that a facility of this type would still be classified as a major source and be subject to the current PSD regulations for review and permitting. An air quality analysis based on specific process emissions and final design is required as part of the permit application and permitting procedures. Ambient air quality monitoring prior to submitting the new permit application may also be required. This analysis must show that all air quality standards will be met and no remaining allowable increment will be exceeded before the air quality permit can be granted. As discussed earlier, the refined total emission estimates and general stack parameters for the proposed CRDC refinery were available. Because of the increases in the estimated proposed emissions, changes in air quality regulations and changes in the ambient conditions in the Georgetown area, an additional air quality analysis was warranted.

(a) Methodology. Both short- and long-term air quality impacts resulting from the siting of the proposed facility near Georgetown have been evaluated. Short-term air quality impacts were determined for total suspended particulate (TSP), sulfur dioxide (SO_2), and carbon monoxide (CO) emissions. Long-term impacts were determined for each of the criteria pollutants except carbon monoxide and non-methane hydrocarbon compounds, which do not have long-term air quality standards.

Short-term impacts were estimated using an air quality screening technique. Worst case meteorological conditions that would produce maximum impacts from the proposed facility were determined using the program (PTMAX) that performs an analysis of the maximum concentration from a point source. These worst case meteorological conditions were then used as inputs to determine maximum one-hour average concentrations. The Multiple Point source model with TERrain adjustments (MPTER) program was used as a screening model to determine the maximum 1-hour average concentration impact from point sources (stacks). Adjustment of the maximum 1-hour averages to 3-, 8- and 24-hour averages were made using correction factors as stated in the Guidelines for Air Quality Maintenance Planning and Analysis, Volume 10 (Revised): Procedures for Evaluating Air Quality Impacts of New Stationary Sources 1977. Concentrations at locations where more than one source (stack) influences air quality were also determined through the use of the MPTER computer program. The long-term air quality impacts were analyzed using the Industrial Source Complex Long-Term (ISCLT) computer model. Meteorological data used with the ISCLT model were for the year 1970 at the Air Force Base at Myrtle Beach and years 1968 through 1972 at Charleston, SC; the highest impacts have been reported. Each pollutant is discussed separately, along with the estimated impact from the facility. Maximum short- and long-term pollutant impacts also were determined for the Cape Romain Wildlife Refuge. This was accomplished using the above techniques in determining the maximum one-hour concentration under worst case meteorological conditions at a down wind distance between 27-30 km (17-19 mi). The long-term values were obtained by modeling the appropriate coordinates with the ISCLT computer model.

At the time this document was completed, final design of the Georgetown facility had not been completed. Emission rates and stack parameters used in this air quality analysis represent the latest estimates obtained through correspondence with the CRDC engineering consultants Ford, Bacon & Davis, Inc. Table VII.A-3 is a tabulaton of the stack and emission parameters used in this analysis.

(b) Total Suspended Particulates. Total suspended particulates are very small particles of solid or liquid matter that remain suspended in the air for some period of time. The ambient air quality standards for TSP in South Carolina are 250 $\mu g/m^3$ for a 24-hour average, and 60 $\mu g/m^3$ for an annual

TABLE VII.A-3

ESTIMATED STACK AND EMISSION PARAMETERS
FOR THE CRDC GEORGETOWN REFINERY

CRDC Stack Parameters					Emission Rates g/sec			
No.	Height m.	Diam. m.	Velo. m/sec.	Temp. °K	TSP	SO_2	NO_x	CO
1	30.48	1.93	15.24	755	0.58	0.06	3.05	0.36
2	30.48	2.08	15.24	755	0.42	0.05	2.33	0.36
3	18.29	0.84	15.24	644	0.69	0.08	3.71	0.36
4	18.29	0.91	15.24	644	0.24	0.03	1.21	0.36
5	18.29	0.61	15.24	644	0.18	0.02	1.04	0.36
6	18.29	0.61	15.24	644	0.58	0.06	3.02	0.36
7	18.29	0.61	15.24	644	0.03	0.01	0.20	0.36
8	22.86	1.68	19.81	450	0.16	0.05	0.83	0.36
9	15.24	0.46	4.75	380	-	1.07	-	-
			Totals g/sec		2.88	1.43	15.39	2.88
			Totals Metric tons/yr		90.7	45.3	485.6	90.7

NOTE: Hydrocarbon emissions have been presented in Table VII.A-2

geometric mean. Currently, the proposed locations for the facility would be within an area classified as in attainment of TSP standards and a Class II PSD air quality area.

In discussions with the Department of Health and Environmental Control (DHEC) of South Carolina (Kauthen, personal communication, 1983), the baseline concentration for TSP had been established for the area around Georgetown on August 7, 1977. The remaining TSP allowable increments for Class II areas are 33.2 $\mu g/m^3$ for a 24-hour average and 18.6 $\mu g/m^3$ for an annual geometric mean.

Particulate emissions from the proposed facility are estimated to be less than 90.7 metric tons (100 tons) per year. A significant emission rate for TSP is considered to be 22.6 metric tons/year (25 tons/year); 90.7 metric tons/year (100 tons/year) would classify the proposed facility as a major source of particulate emissions. In accordance with the PSD permit application, the applicant must conduct an analysis to ensure the application of Best Available Control Technology.

Using the PTMAX computer model, the meteorological conditions that would result in the highest ground level TSP concentrations were determined. The modeling indicates that maximum TSP concentrations would occur with wind speeds of 5 to 10 m/sec. (16 to 33 ft/sec) under stability Class C.

The MPTER computer model was used to estimate the downwind TSP concentrations from the proposed refinery under a number of wind speeds and stability Class C. The maximum 1-hour average TSP impact of 24.6 $\mu g/m^3$ occurred with a wind speed of 7 m/sec (23 ft/sec) at approximately 0.4 km (0.25 mi) downwind of the proposed facility.

Using a conversion factor range of 0.6 to 0.2, (EPA-450/4-77-001, Oct. 1977) for the maximum 1-hour to a maximum 24-hour concentration results in an estimated 24-hour maximum TSP concentration range of 14.8 $\mu g/m^3$ to 4.9 $\mu g/m^3$. Currently there is an allowable TSP increment of 33.2 $\mu g/m^3$ remaining for the Georgetown Class II area. If the proposed refinery is built it would consume as much as 14.8 $\mu g/m^3$ of the increment, leaving 18.4 $\mu g/m^3$ 24-hour TSP increment.

The highest TSP concentrations resulting from maximum impacts from the proposed refinery and the existing sources would occur if the Winyah Power Plant air emission plumes overlap the refinery plumes. The expected maximum combined TSP impact would be approximately 70 $\mu g/m^3$ 1-hour average. Conversion to a 24-hour average gives a 42 $\mu g/m^3$ 24 hour impact. This maximum impact is below the primary and secondary NAAQS of 260 $\mu g/m^3$ and 150 $\mu g/m^3$, and is also below the South Carolina 24-hour TSP standard of 250 $\mu g/m^3$.

The ISCLT computer model was used to estimate yearly averages for the existing sources in the Georgetown area and the yearly average for the CRDC proposed refinery. The average annual TSP impact from the existing sources indicated that the largest concentrations would occur in downtown Georgetown. The highest annual TSP average modeled from the existing sources was 9.7 $\mu g/m^3$. The highest value modeled from the CRDC refinery was 1.0 $\mu g/m^3$ and occurred to the west of Georgetown and north of the proposed sites. Though the highest yearly impacts from the proposed facility and the existing sources do not occur at the same location, the combined impact of 10.7 $\mu g/m^3$ would not exceed the annual 75 $\mu g/m^3$ NAAQS or the 60 $\mu g/m^3$ annual TSP standard of South Carolina.

The TSP impact on the Cape Romain National Wildlife Refuge was also modeled. The highest TSP concentrations at 27 km (17 mi) downwind of the facility occurred with 2.0 m/sec (6.5 ft/sec) winds under stability Class E conditi ns. The maximum 1-hour TSP impact on Cape Romain National Wildlife Refuge from the CRDC proposed refinery was 3.9 $\mu g/m^3$ giving a maximum 24-hour average of 2.3 $\mu g/m^3$. The maximum annual TSP impact was 0.06 $\mu g/m^3$. Currently, existing sources in the Georgetown area consume 3.8 $\mu g/m^3$ of the allowable 10 $\mu g/m^3$ 24-hour TSP and 0.2 $\mu g/m^3$ of the allowable 5 $\mu g/m^3$ annual TSP increment. It can be concluded that there is sufficient TSP increment remaining at the Cape Romain National Wildlife Refuge for locating the proposed facility at the proposed site near Georgetown.

In summation, the TSP analysis indicates that the proposed facilty would neither cause TSP concentrations to exceed ambient air quality standards, or consume all of the remaining allowable TSP increment for the Georgetown area or the Cape Romain National Wildlife Refuge.

(c) Sulfur Dioxide. South Carolina's ambient air quality standards for sulfur dioxide are 1300 $\mu g/m^3$ 3-hour average, 365 $\mu g/m^3$ 24-hour average, and 80 $\mu g/m^3$ annual average.

All of South Carolina is in attainment of the sulfur dioxide standards. According to DHEC, the baseline date and concentrations have not been set. However, Units 3 and 4 of the Santee Cooper Winyah Power Plant consume allowable SO_2 increments. The baseline date will be set when the first completed application is submitted by a major stationary source or major modification subject to the requirements of 40 CFR 52.21, air quality regulations.

Sulfur dioxide emissions from the proposed facility are estimated to be less than 45.3 metric tons/year (50 tons/year). This emission range would not classify the proposed source as a major stationary source. However, 36.3 metric tons (40 tons) and greater of SO_2 per year is considered a significant emission rate. An air quality impact analysis and the application of the Best Available Control Technology would be required for the PSD permit. The application for a PSD permit will set the SO_2 baseline date and concentrations for the Georgetown area.

Currently, the remaining allowable increments for SO_2 in the Georgetown Class II area are 274.6 $\mu g/m^3$ 3-hour average, 62.6 $\mu g/m^3$ 24-hour average and 19.6 $\mu g/m^3$ annual average. The remaining allowable SO_2 increments at the Cape Romain Class I area for consuming sources in the Georgetown area are 5.3 $\mu g/m^3$ 3-hour average, 1.1 $\mu g/m^3$ 24-hour average and 1.8 $\mu g/m^3$ annual average.

Modeling results indicate that the maximum SO_2 1-hour impact would be 137 $\mu g/m^3$. Using the conversion factor range of 1.0 to 0.8 given in the Guidelines for Air Quality, a 3-hour average maximum impact of 137 to 109 $\mu g/m^3$ is obtained. Using the conversion factor range of 0.6 to 0.2 for the 1-hour to 24-hour conversion gives a 24-hour average of 82 to 27 $\mu g/m^3$. The maximum SO_2 annual average impact modeled using the ISCLT model was 1.3 $\mu g/m^3$ SO_2.

The analysis indicates that there is sufficient 3-hour and annual SO_2 increment remaining in the Georgetown area for the impacts from the proposed facility. However, the analysis also indicates that the CRDC facility has the potential to consume more than the remaining allowable 24-hour SO_2 increment of 1.1 $\mu g/m^3$. The SO_2 impact from the proposed refinery on the Cape Romain National Wildlife refuge was modeled to be 3.5 to 2.8 $\mu g/m^3$ 3-hour average, 2.1 to 0.7 $\mu g/m^3$ 24-hour average, and 0.04 $\mu g/m^3$ annual average. From the analysis, the proposed refinery has the potential to consume more than the remaining allowable 24-hour SO_2 increment for the Cape Romain Class I area.

The conservative approach of this screening analysis with the use of worst case conditions has shown the potential for the CRDC proposed facility to consume all of the remaining 24-hour SO_2 increment in both the Georgetown area and in the Cape Romain National Wildlife Refuge. This modeling approach has also indicated the possible exeedance of SO_2 ambient air quality standards due to the large influence of the Winyah Power Plant emissions on the Georgetown area. However, an air quality analysis based on specific process emissions and final design must show that all air quality standards will be met and no remaining allowable increment will be exceeded before the required air quality permit can be obtained from DHEC. Attention is directed to the letter dated May 15, 1984 in Appendix B from the applicant's consultant, Ford, Bacon & Davis, describing its SULFTEN System which was not incorporated into the air quality evaluation because of insufficient time. The SULFTEN System could greatly reduce the emission of sulfur dioxide from that evaluated in this EIS.

(d) Carbon Monoxide. The air quality standards for CO are 40 mg/m^3 for a 1-hour average and 10 mg/m^3 for an 8-hour average.

The area of the proposed source is in attainment of the CO standards. There are no increment limitations for CO under PSD regulations. However, the regulations do require air quality analyses to be conducted on sources emitting CO in significant amounts. The estimated CO emission rate for the proposed facility is less than 90.7 metric tons/year (100 tons/year). This is considered a significant emission rate requiring an air quality analysis and the application of the Best Available Control Technology. The maximum CO impact from the proposed facility was modeled to be 0.027 mg/m^3. Conversion to an 8-hour average, accomplished using a 0.9 mulitplier, resulted in an 8-hour impact of 0.024 mg/m^3. Both of these values are well below the ambient standards for CO.

Carbon monoxide is also emitted from the operation of vehicle internal combustion engines. It has been estimated that the proposed facility would cause an increase in local vehicle trips per day (Bruce J. Muga and Associates and Wilbur Smith and Associates, 1981). These 900 trips would be broken down into 355 trips for heavy duty vehicles and 545 trips for general passenger vehicles.

The proposed facility's traffic would be serviced by SC 42, which has an existing traffic volume of approximatley 3,300 vehicles per day. The proposed facility would cause an increase in traffic volume on SC 42 to 4,200 vehicles per day. Typical maximum hourly traffic volumes occur during morning hours around 7:00 and during evening hours around 4:00. These peak traffic hours could have as much as 10 percent of the daily traffic volume. Using a 0.10 factor to convert daily traffic to a maximum hourly volume, SC 42 could have a maximum hourly traffic volume of 330 vehicles for existing traffic and 420 vehicles with the proposed refinery traffic added.

Maximum carbon monoxide concentration from existing traffic at a point just off the roadway could be approximately 1.7 mg/m^3 for a 1-hour average. With the additional traffic from the proposed refinery, this maximum value could increase to 2.3 mg/m^3 1-hour average. The standard for carbon monoxide is 40 mg/m^3 1-hour average. It is not expected that the increase in vehicular traffic generated by the CRDC proposed facility will cause adverse impacts on air quality along highways traveled.

Concentrations of CO can be expected to be high in areas of high traffic density, such as urban areas. Downtown Georgetown is located at the crossroads of Routes 17, 17A and 701. It is expected that the downtown area of Georgetown would experience the highest CO concentration within 10 kilometers (6.2 miles) of the proposed sites. The CO concentrations would be mainly due to CO emissions from vehicular traffic. It is not expected that there would be violation of the air quality standards due to the impact from the proposed facility.

(e) Nitrogen Oxides. Nitrogen oxides (NO_x) are a class of pollutants formed by the combustion of fuel at very high temperatures (generally above 1200°F). The level of this class of pollutants is of concern due to its role in the formation of ozone and acid rain.

All of South Carolina is in attainment of the NO_2 ambient air quality standard, 100 $\mu g/m^3$ annual average NO_2 concentration. Estimated emissions of NO_x from the proposed facility are 485.6 metric tons/year (535 tons/year). This emission rate would classify the proposed facility as a major source for NO_x, requiring the application of the Best Available Control Technology.

The ISCLT modeling results indicate that the maximum annual NO_x impact would be approximately 5.0 $\mu g/m^3$.

As with SO_2 emissions, the Santee Cooper Winyah Power Plant accounts for approximately 81 percent of the area's industrial NO_3 emissions. The estimated maximum annual NO_x concentration from existing sources in the Georgetown area is 2.3 $\mu g/m^3$. The combined annual impact with the proposed facility would be 7.3 $\mu g/mm^3$. This maximum impact is well below the 100 $\mu g/m^3$ annual air quality standard.

Nitrogen oxides are also emitted from motor vehicle operations. Total NO_x impact for the downtown area, industrial plus motor vehicle impacts, is not expected to result in violations of the ambient air quality standard.

(f) Hydrocarbons and Ozone. Hydrocarbon emissions are of concern due to their role in the production of ozone in the atmosphere. Ozone, a secondary pollutant, generally is not directly emitted from pollutant sources but is formed in the atmosphere by the reaction of other pollutants and sunlight. In the absence of appreciable amounts of organic compounds (hydrocarbons), a chemical equilibrium established between ozone, nitric oxide, and nitrogen dioxide results in low levels of atmsopheric ozone. In the presence of appreciable amounts of organic compounds, the equilibrium shifts towards higher ozone econcentrations. South Carolina's strategy to achieve attainment is statewide application of volatile organic compound regulations.

The ambient air quality for non-methane hydrocarbons of South Carolina is 160 $\mu g/m^3$ over a 1-hour average. The rate of reaction for the formation of ozone varies with the type and class of hydrocarbons undergoing reaction. Long range transport of these reactants can cause increases in ozone at great distances downwind of hydrocarbon sources.

The estimated emissions of hydrocarbons from the proposed facility are 1,888 metric tons/year (2,080 tons/year). These emissions are mostly fugitive emissions from leakages from valves, seals, process drains, etc. These fugitive air emissions may cause a violation of the hydrocarbon and ozone standards downwind from the facility. However,an air quality analysis based on specific process emissions and final design must show that all air quality standards will be met and no remaining allowable increment will be exceeded before the required air quality permit can be obtained from DHEC. With the use of the Best Available Control Technology on the hydrocarbon emission sources, the impact on the ambient hydrocarbon and ozone levels will be minimized.

(g) Summary of Air Quality Analysis. The analysis performed indicates that there could be violations to air quality standards for the non-methane hydrocarbon and ozone. There is also a possibility that the proposed refinery could consume all of the remaining 24-hour SO_2 increment in both the Georgetown Class II area and the Class I area of Cape Romain.

However, the analysis required for the air quality permit, which is addressed on page VII.A-14, must show that all standards will be met and that no remaining allowable increment will be exceeded before the air quality permit can be granted. The following table presents pollutant impact estimates along with air quality standards:

Pollutant	Measuring Interval	Air Quality Standard $\mu g/m^3$	Proposed Facility Maximum Impact $\mu g/m^3$	Modified Existing Conc. plus Refinery
Suspended Particulate	24-hour	250	14.8	42
	annual	60	1.0	10.7
Sulfur Dioxide	3-hour	1,300	137	436
	24-hour	365	82	261
	annual	80	1.3	8.0
Carbon Monoxide	1-hour	40,000	27	*
	8-hour	10,000	24	*
Nitrogen Dioxide	annual	100	5.0	7.3*

*Carbon Monoxide and nitrogen oxides are mainly emitted by vechicular sources. Specific concentrations for the downtown Georgetown area with these emissions accounted for, is beyond the scope of this document.

It should be noted that the impacts given here are greater than those predicted previously on page VII.A-12. These earlier data were given in the original process permit application and based upon SCDHEC data on allowable emissions rates that are no longer valid.

(3) Impacts on Sensitive Sites. The air quality impacts on sites sensitive to air quality in the Georgetown area (detailed in Section VI, B.1.f.) are discussed below:

The City of Georgetown is located approximately two to three kilometers (1.2 to 1.8 miles) from the proposed sites. Modeling results indicate that pollutant impacts would be:

TSP	5.7 - 6.9 $\mu g/m^3$	- 24-hr. avg.
	0.6 - 0.2 $\mu g/m^3$	- annual avg.
SO_2	30.0 - 18.0 $\mu g/m3$	- 3-hr. avg.
	18.0 - 10.8 $\mu g/m^3$	- 24-hr. avg.
	0.6 - 0.1 $\mu g/m^3$	- annual avg
CO	11.0 - 12.5 $\mu g/m^3$	- 1-hr. avg.
	9.9 - 11.0 $\mu g/m^3$	- 8-hr. avg.
NO_x	3.2 - 1.0 $\mu g/m^3$	- annual avg.

The Class II PSD area where the proposed site would be located encompasses all the area (including area sites listed in Section VI B.1.f.) around Georgetown except the Cape Romain National Wildlife Refuge Class I area. The impacts on the Class II areas would be the maximum impacts from the proposed facility. These impacts are detailed in the summary of Subsection (2) Additional Air Quality Study of this Section.

The estimated maximum air quality impact on the Cape Romain Class I area is as follows:

TSP	2.3 $\mu g/m^3$	- 24-hr. avg.
Less than	0.1 $\mu g/m^3$	- annual avg.
SO_2	3.5 $\mu g/m^3$	- 3-hr. avg.
	2.1 $\mu g/m^3$	- 24-hr. avg.
Less than	0.1 $\mu g/m^3$	- annual avg.
CO	5.3 $\mu g/m^3$	- 1-hr. avg.
	4.8 $\mu g/m^3$	- 8-hr. avg.
NO_x	0.3 $\mu g/m^3$	- annual avg.

For comparative purposes, the impacts for Class I (Cape Romain) and Class II (Georgetown County) areas are shown in the following table:

PSD Class I and Class II Impacts

	Class I Impacts (Cape Romain)		Class II Impacts (Georgetown County)	
Pollutant	Remaining Increment ($\mu g/m^3$)*	Projected Refinery Impact ($\mu g/m^3$)	Remaining Increment ($\mu g/m^3$)	Projected Refinery Impact ($\mu g/m^3$)
TSP 24-hr	6.2	2.3	33.2	14.8
TSP annual	4.8	0.06	18.6	1.0
SO_2 3-hr	5.3	3.5	276.6	137
SO_2 24-hr	1.1	2.1	62.6	82
SO_2 annual	1.8	0.04	19.6	1.3

*Based on Screening analysis performed for this EIS. A more detailed study would be required for a PSD permit.

Ambient air quality standards have been designed and set to protect the public health and welfare. In general, the air quality impacts from the proposed facility are small.

(4) Synergistic Effects. Synergism, as applied to the observed effects of air pollution, refers to the difference between the actual and expected event. When the effect of two air pollutants acting together is greater than the sum of effects resulting from each individually, the pollutants are known to have synergistic effects.

Increases over expected health effects are observed in certain population groups, namely those with chronic respiratory conditions or advanced age. In this case the observed health effect is manifested at lower air pollutant concentrations. At higher concentrations the severity of the observed health effect is increased (Chanlett, 1973).

The most common synergistic effect is the adsorption of gases and vapors (sulfur dioxides and nitrogen oxides) on particulate matter, resulting in increased health effects among the general population as documented in various historical air pollution episodes. In the case of the CRDC, facility emissions of sulfur oxides, nitrogen oxides and particulate matter are not expected to impact the local air quality. For this reason, in the absence of other contributing sources, the potential for synergistic effects of this type is minimized.

Hydrocarbons, nitrogen oxides, and ozone interact by photochemical processes. The direct effect of those pollutants is not of primary concern. The reaction products from the pollutant interaction, however, produce compounds with increased effect on man and the environment. Hydrocarbon emissions from the CRDC facility may contribute to the levels of these compounds in the atmosphere.

Laboratory studies have been used to estimate the potential impacts of pollutant interactions. Reactions between hydrocarbons and nitrogen oxides produce aldehydes and (near completion) ozone and peroxyacetyl nitrate; at 3 ppm of hydrocarbon and 1 ppm of nitrogen oxide, appreciable concentrations of ozone resulted from photoxidation (Korth, 1964). No simple correlation to predict either absolute or relative ozone yield from initial concentrations of hydrocarbons and nitrogen oxides has been discovered.

(5) Visibility Impairment. Federal regulations define "visibility impairment" as any humanly perceptible change in visibility from that which would have existed under natural conditions. The regulations require visibility impairment evaluations of emissions sources. These evaluations are to determine the potential impacts on visibility at federal Class I air quality areas.

Objects are visually perceived by the eye-brain mechanism by comparing the light intensities of different objects at different wavelengths in the visual field. Air pollution can change the light intensities of objects by light scattering or by light absorption. If these effects are humanly perceptible, an impairment to visibility has occurred.

The Workbook for Estimating Visibility Impairment, prepared for USEPA, provides three levels of screening techniques for assessing visibility impairment from a single emissions source. The level-1 analysis involves a number of conservative screening tests that permit the elimination of further, more detailed and complex

analysis of sources with little potential for impact on visibility. If the level-1 analysis indicates that the source could cause significant impairment during hypothetical, worst case meteorological conditions, a level-2 analysis would be performed. If not, further analysis is unnecessary. The level-2 analysis estimates impacts during worst case conditions but uses source- and site-specific conditions. If the level-2 analysis indicates the possibility of significant or adverse visibility impairment under actual conditions, a level-3 analysis is recommended. The purpose of the level-3 analysis is to provide an accurate description of the magnitude and frequency of occurrence of the impacts. Detailed instructions are not provided in the workbook for a level-3 visibility analysis. A brief outline of some important elements of such a detailed analysis is given.

The level-1 visibility screening analysis as outlined in the Workbook for Estimating Visibility Impairment was performed for the proposed Georgetown Refinery. Information needed to conduct the analysis is as follows:

- Minimum distance of the emisions source from the potentially affected Class I area in kilometers;
- Location of the emissions source and Class I area;
- Particulate emissions rate in metric tons/day;
- NO_x emission rate in metric tons/days; and
- SO_2 emission rate in metric tons/day.

The locations of the proposed refinery are two sites just outside of Georgetown, South Carolina. The sites would be located approximately 27 km (16.7 mi) north of the Cape Romain National Wildlife Refuge, a federal Class I air quality area. The estimated emissions of the proposed refinery are presented below:

Pollutant	Estimated Emissions	
	Tons/Year	Metric Tons/Day
Sulfur Dioxide	50	0.1243
Particulates	100	0.2485
Carbon Monoxide	100	0.2485
Nitrogen Oxide	535	1.3297
Hydrocarbons	2,080	5.1697

The level-1 analysis involves a number of calculations to determine values for three contrast parameters. Parameter C_1 is the plume contrast against the sky, C_2 is the plume constrast against the terrain, and C_3 is a change in the sky/terrain contrast caused by primary and secondary aerosol. The following values were calculated for the three contrast parameters:

Parameter	Calculated Values
C_1	-.0108
C_2	+.0078
C_3	+.00004

The workbook states that if the absolute value of any one of the calculated contrast parameters is greater than 0.10, the emissions source fails the level-1 visibility screening test, and further screening analysis is required.

The absolute values of the contrast parameters calculated for the Georgetown refinery were all below 0.10. This would indicate that it is unlikely that this emission source would cause an adverse visibility impairment impact on the Cape Romain National Wildlife Refuge; therefore, further analysis of potential visibility impacts would be unnecessary.

d. Health Effects

(1) Plant Worker Exposure

(a) Introduction. As required by regulations under the Occupational Safety and Health Act (29 CFR 1910), it is the responsibility of the employer to provide a safe and healthful workplace for its employees. To this end, through an ongoing research program, the Occupational Safety and Health Administration (OSHA) promulgates and enforces regulations limiting worker exposure to chemical, physical, and biological hazards to safe levels (OSHA, 1981).

The proposed refinery to be developed by the CRDC is expected to contain characteristic processes with potential occupational health hazards resulting from air emissions. The following sections outline these potential hazards with respect to proposed control strategies and evaluation techniques.

(b) Work Force Description. The proposed CRDC facility is expected, at completion, to employ between 100 and 120 people (USACoE, 1978). Employment can be anticipated to be 90 percent male (MITRE Corp., 1981) with 10 percent of the workforce in a management/supervisory position. In a refinery of this type, approximately 60 percent of the workforce should be actively engaged in production with the balance of the employees in support categories (i.e., welders, pipefitters, electricians, and other maintenance personnel).

Nearly all of the production and support personnel may be exposed to airborne occupational hazards. In addition, other workers such as construction contractors and truckdrivers or transport workers may be exposed. Female employees of childbearing age present a special concern since workplace hazards may have an adverse effect on the developing fetus.

(c) Hazardous Exposures. Occupational exposure to airborne contaminants in the refinery operations will include hydrocarbons (acyclic, alicyclic, aromatic, phenolic, polynuclear aromatic), sulfur compounds (hydrogen sulfide, thiol), nitrogen compounds (ammonia, nitrosamines), and metals (crude contaminants, catalysts; Davis and Floyd, 1978). These compounds are present as particulates, vapors, gases, or mists.

Traditionally, these identified exposures must be evaluated to determine their magnitude and assess the occupational health impact. Preliminary evaluations, conducted by Davis and Floyd Engineers, Inc. for CRDC, indicate the proposed facility emission of air contaminants on a yearly basis, as well as by process (Davis and Floyd, 1983). However, it is not possible to use this data to determine a potential long-term worker exposure to airborne contaminants.

The design and operation of the equipment must result in workplace exposure levels that are less than the Permissible Exposure Limits (PEL) established by OSHA. Table VII.A-4 lists these PELs for the known refinery air emissions.

Actual occupational exposure to airborne contaminants may occur singly or in combination; as a result, the actual health impacts may vary in type and intensity. In addition, the susceptibility of the individual worker to airborne contaminants varies (NIOSH, 1977).

Of particular concern in refinery process emissions is the presence of known carcinogens, such as the polycyclic aromatic hydrocarbons (i.e., Benzo [a] pyrene and 3-Methylcholanthrene), benzene, coke emissions, and metals (nickel).

Additional hazardous exposures which impact the development of occupational health problems include thermal stress (work in hot environments), entry into confined spaces, and noise exposure.

(d) Occupational Health Effects - Historical. A wealth of data is available on the toxicology of the various process emissions associated with the refinery operations. To date, however, the toxicology data have not been combined with exposure measurements to conduct a rigorous risk assessment. Such a study would develop mortality records of refinery workers enabling a valid prediction of future occupational disease based on cumulative exposure. Upon completion of an historical review of occupational health effects and the development of a valid risk assessment, toxicology data may also be used to predict long-term community health impacts.

Numerous epidemiological studies have indicated that refinery workers are not subject to increased health risks over the general population (Wade, 1963; Baird, 1967; API, 1974; Theriault and Goulet, 1979). The Wade study of 1962 matched pairs of exposed and non-exposed refinery workers showed no increased skin cancers during the 12-year study period. Baird reported similar results in a study of cancer mortality among 15,437 Humble Oil Refinery workers over a 29-year period. The 1974 API study of 20,163 petroleum refinery workers at 17 refinery locations showed no increased mortality in all disease categories for the given 10-year period. Similar data were obtained in a 1979 Canadian study by Theriault and Goulet.

Recent findings, however, have indicated increased cancer risks among refinery and petrochemical workers. One study (Harris et al., 1979) of the Canadian refining industry showed increased risk of esophageal and stomach cancers for workers exposed to petroleum and petroleum products. Similar work in one U.S. refinery (Thomas et al., 1980) showed that increased cancers were directly related to length of employment; however, no specific data on worker exposures was available to develop causal relationships.

TABLE VII.A-4

OSHA PERMISSIBLE WORKPLACE EXPOSURE LIMITS
FOR REFINERY AIR EMISSIONS

Category	Process	Contaminant	OSHA PEL
Hydrocarbons	Heating and flashing units		
1. Acyclic		Hexane	500 ppm
2. Alicyclic		Cyclohexane	300 ppm
3. Aromatic		Toluene	200 ppm
4. Phenolic (Coker)		Phenol	5 ppm
5. Polynuclear (Coker) Aromatic		CTPV	0.20 mg/m^3 (Benzene soluble)
Sulfur Compounds	Desulfurization process	Hydrogen sulfide Sulfur dioxide	20 ppm 5 ppm
Nitrogen Compounds	Process heaters, Gas Turbine	Nitrogen dioxide	5 ppm
Metals	Catalytic cracking	Platinum Nickel (sol. metal)	0.002 mg/m^3 1 mg/m^3

SOURCE: OSHA, 1981

Epidemiological studies on general industrial workers exposed to refined petroleum products have shown these compounds to cause dermal, eye, nose, and throat irritation; menstrual disturbances; leukemia (benzene); polyneuropathy; and neurological dysfunction (NIOSH, 1977).

(e) Control Strategies for Health Hazards. OSHA emphasizes the use of engineering controls to limit worker exposure to airborne occupational hazards. These controls are developed by designing the process to minimize potential emissions or by installing exhaust ventilation systems to remove any generated emissions at the source. Alternatives to engineering controls include administrative measures (shortened work shifts or rotation of employees from high to low hazard areas) and the use of personal protective equipment (respirators, protective clothing).

The control of occupational health hazards in the petroleum refining industry is directly related to development of new processes (MITRE Corp., 1981). Increased catalytic cracking, hydroheating to process some crudes, and reforming-alkylating and isomerizing to improve gasoline octane ratings have created new potential health hazards. The decrease in the use of lead-based additives requires increased use of catalytic reforming and aromatic extraction units which result in process streams of more toxic (aromatic) hydrocarbons. The use of higher sulfur content crude results in accelerated deterioration of refinery equipment and increased emissions of sulfur compounds. Control of these new refinery processes is aided by improved inspection and maintenance techniques, new and better materials of construction, and advanced instrumentation. In addition, automation of refinery processes has resulted in the reduced necessity for locating employees in high-hazard areas (MITRE Corp., 1981).

Process descriptions for the proposed facility (Davis and Floyd Engineers, Inc., 1978b) express the degree of airborne emission control to be incorporated in the facility operation. The controls center around the use of vapor recovery systems, flue gas desulfurization processes, periodic maintenance programs for all vents, mechanical seals (on valves, process tanks, and compressors), and duplication/back-up systems for diversion of process flow around uncontrolled emission points.

The effectivness of the proposed emission control strategy on occupational exposures can only be assessed after presentation of more detailed plans and specifications. Implementation of an exposure-monitoring program at facility start-up will verify the degree of control. Exposure monitoring would include air sampling in and around process equipment and work locations to determine actual conditions, as well as medical monitoring of exposed employees to assess worker health. Medical monitoring is particuarly critical in the evaluation of carcinogenic chemical exposures.

(2) Community Exposure

(a) Local Air Quality. Dispersion modeling (discussed previously in this document) of refinery emissions from the proposed CRDC facility shows that the resultant impact on ambient air quality within the Georgetown area will not be significant for total suspended particulates, nitrogen oxides, sulfur oxides, and carbon monoxide. With the refinery in operation, the levels for these criteria pollutants are expected to remain well below the National Ambient Air Quality Standards for community exposure.

Hydrocarbon emissions from the proposed facility are expected to affect the local air quality, but the degree of the effect is subject to the results of more detailed process planning and emission inventories. The local population will face increased exposure to hydrocarbons. In addition, photochemical oxidation of the hydrocarbon pollutants with ozone may result in photochemical "smog" associated historically with air pollution episodes in Los Angeles County, California.

(b) Historical Health Effects. Little information is available in the literature which documents community health effects from refinery emissions. A recent publication indicates a need for research to increase such information (MITRE Corp., 1981).

In general, however, information is available that describes observed health effects from hydrocarbon exposure. Measured hydrocarbon levels (aldehydes) from 0.035 to 0.35 ppm produced eye irritation (Renzetti, and Bryan, 1961). Predictive studies on polycyclic organic compounds (NAS, 1972) indicated potential carcinogenic risks, and comprehensive literature reviews discuss potential health effects associated with a broad range of hydrocarbons as air pollutants (NAS, 1976). Additional studies indicate increased mortality in geographical areas where refineries are located. One survey (Blot et al., 1977) of cancer mortality in males of 39 U.S. counties with petroleum industries showed significantly higher cancer rates for 23 cancer sites (as compared to 117 control counties without petro-chemical industries). Another study (Menck et al., 1974) showed higher mortality rates in the heavily industrialized Los Angeles County. The studies have not been correlated with air quality data. Review of these sources indicates the potential for adverse health effects and emphasizes the need for a strong control program.

(c) Exposure Control. Although characteristic hydrocarbon emissions are anticipated, the actual emissions from the CRDC facility are directly related to process design and control. Air quality is maintained through engineering factors, such as mechanical seals, rupture discs, vapor recovery systems, as well as through scheduled maintenance and standard operating procedures designed to reduce emissions.

The effectiveness of the proposed hydrocarbon control program with respect to off-site and community exposure can be demonstrated through ambient air monitoring. Measurements from such a monitoring program must be correlated with meteorological data (wind speed/direction, temperature, humidity, lapse rate). Results of the monitoring program should be compared to the National Ambient Air Quality Standards.

(d) Odor

(i) Odor Sources. The proposed CRDC facility will operate typical refinery process systems. Although these unit processes are geared toward closed-loop operation, odors are produced and form the basis for a nuisance complaint from community residents. Typical sources of odors for the proposed processes include:

Catalytic reoperators - hydrocarbons, ammonia, organic acids, sulfur oxides and aldehydes

Pumps and compressors - mercaptans and hydrogen sulfide;

Storage vessels - hydrocarbons

Catalytic cracking - sulfur compounds

Blowdown - sulfides, mercaptans, ammonia

The intensity of offshite odors is directly related to the quantity permitted and the dispersion produced by the meteorological conditions. In the case of strong odorants such as hydrogen sulfide and mercaptans, very low concentrations will result in perceived malodor.

(ii) Odor Control. Common odor control methods in the refinery industry center around process design. The venting and circulation of odorous process emissions are developed in such a way as to provide maximum odor control through mechanical means (via seals, casings, and pressurized packing glands), vapor recovery (absorption and/or oxidation), and dispersion.

Specific odor control techniques (Davis and Floyd Engineers, Inc., 1978d) to be used at the CRDC facility include:

- Reduction of excess air and peak flame temperature through use of special combustion equipment
- Use of mechanical seals, double outboard seals, labyrinth seals, oil seals, quick change blinds, and rupture discs, plus limited use of flanges;
- Use of a vapor recovery system, including repressurization and thermal oxidation of odorous off gases; and
- Combined Claus and Stretford sulfur recovery.

e. Air Quality Implications of Crude Oil and Refined Product Spills. Hydrocarbons are compounds with molecules consisting primarily of hydrogen and carbon. Crude oil is a mixture of hydrocarbons which can be made up of just a few carbon atoms or up to macromolecules with hundreds of carbon atoms. An accidental spill of crude oil or petroleum products usually will result in a short-term air quality impact of immediate concern due to the flammable and toxic characteristics of hydrocarbon vapors.

The volatility of hydrocarbons is approximately determined by their carbon number. Hydrocarbons with a carbon number (i.e., number of carbon atoms in each molecule) greater than about 12 are generally not sufficiently abundant to reach atmospheric concentrations of concern in the gas phase. Hydrocarbons having a carbon number of one to four are gaseous at ordinary temperatures, while those with a carbon number of five or more are liquids or solids in the pure state. Liquid mixtures of hydrocarbons, such as crude oil, may include some proportion of compounds which, in the

pure state, would be either gases or liquids (U.S. Department of Health, Education and Welfare, 1970). Assays of the Venezuelan crudes (Section VII.B.2.b.) indicate that volatile components of the oil range from five to 10.7 percent. Various studies indicate that during a spill the volatile components were lost during a one to three hour period (Kullenberg, 1982).

The processes of evaporation and atmospheric dispersion are complex and dependent upon many variables. Environmental factors such as ambient temperature, wind speed, surface area of the spill, and surface roughness (spill on water) all contribute greatly to the rate of evaporation. When the evaporation rate is significantly high, vapor concentrations above and downwind of the spill can be toxic and often flammable. The extent that these hazardous vapor concentrations (hazard zones) travel before atmospheric dispersion dilutes the pollutants to acceptable levels is beyond the scope of this study. Such information may be found in the Coast Guard's handbook, Chemical Hazard Response Information System (CHRIS), designed to provide information during emergencies involving the water transport of hazardous chemicals.

In general, hydrocarbons released into the atmosphere from a spill would have short-term impacts once dispersed and diluted beyond the hazard zones. The volatile fractions of a petroleum spill usually vaporize within a short time (one to three hours) after the spill occurs; it is this quick evaporation that produces the hazardous concentrations.

The seventeen spill scenarios involved have been presented in Table VII.B-14. Spill scenario Cases 1, 2, 4, 8, 9, 10 and 17 all involve a spill of refined product, usually JP-4 (jet aviation fuel). This refined product is a mixture of various volatile fractions. Any spill involving this type of product has the potential to catch fire. The volatile nature of this product usually results in both a flammable and toxic hazard zone at the spill site. For large spills of this product, as in Cases 1, 8, 9 and 10, the hazard zones could persist down-wind of the spill. If a large spill of JP-4 should occur, temporary evacuation of populated areas within the hazard zones may be required.

Spill scenario Cases 2, 3, 5, 6, 7, 9, 11, 12, 13, 14, 15 and 16 all involve a spill of crude oil. Crude oil contains the same volatile fractions as in JP-4 in a less concentrated form. The evaporation rate of the volatile fractions of crude would be less than that of the refined product, and would significantly reduce the extent of the hazard zones for crude oil spills as compared to those for the refined product spills. The hazard zones of the large crude oil spills, as for the refined product spills, could impact populated areas and may require temporary evacuation.

(3) Cumulative Air Quality Impacts

Cumulative impacts on the environment are defined as the incremental effects of an action added to other past, present, and reasonably foreseeable future actions regardless of what agency or person undertakes such actions. In the case of the proposed CRDC refinery, cumulative air quality impacts would refer to the emission impacts from the proposed refinery added to the emissions impacts from other sources within the Georgetown area. These cumulative air quality impacts have been compared to the ambient air quality standards in order to determine if the facility would cause standard violations. Facility impacts and existing source impacts have

been discussed in the additional study subsection above. The analysis performed for this impact statement used design parameters that at the time of preparation represented the best estimates of the actual facility. It must be noted that at that time the final design had not been completed.

Currently there are 11 sources within the Georgetown area listed in DHEC's emissions inventory. The existing total emissions and the proposed CRDC refinery estimated emissions are compared in the following table:

	Existing Sources Total Emmissions		CRDC Refinery Estimated Emissions	
Pollutant	Metric Tons/Year	(Tons/Year)	Metric Tons/Year	(Tons/Year)
TSP	1,520.5	(1,675)	90.7	(100)
SO_2	46,884.2	(51,646)	45.3	(50)
CO	1,387.1	(1,528)	90.7	(100)
NO_x	17,878.2	(19,694)	485.6	(535)
HC	477.5	(526)	1,888.2	(2,080)

The downtown Georgetown TSP concentrations are the result of the impact from a number of existing industries in Georgetown. Maximum concentrations recorded in 1982 at downtown locations were 131 $\mu g/m^3$ (24-hr average) and 50 $\mu g/m^3$ (annual geometric mean). The estimated TSP maximum impact from the proposed refinery is expected to occur 0.4 km (0.2 mi) from the proposed site, with estimated maximum impact concentrations of 14.8 $\mu g/m^3$ (24 hr average) and 1.0 $\mu g/m^3$ (annual average). Adding the maximum TSP concentrations from downtown areas (1982) to the estimated maximum TSP emission concentrations from the proposed refinery gives cumulative maximum TSP impacts of 145.8 $\mu g/m^3$ (24-hr average) and 51.0 $\mu g/m^3$ (annual average). These cumulative maximum impacts are below the ambient air quality standards for TSP of 150 $\mu g/m^3$ (24-hr average) and 60 $\mu g/m^3$ (annual geometric mean).

Estimated maximum SO_2 impacts from the proposed facility are 137 $\mu g/m^3$ (3-hr average), 82 $\mu g/m^3$ (24-hr average) and 1.3 $\mu g/m^3$ (annual average). The conservative approach of this screening analysis has shown the potential for the SO_2 emissions impacts to consume more than the remaining 24-hr SO_2 increment in both the Georgetown area and in the Cape Romain area. However, an air quality analysis based on specific process emissions and final design must show that all air quality standards will be met and no remaining allowable increment will be exceeded before the required air quality permit can be obtained from DHEC.

Attention is directed to the letter dated May 15, 1984 in Appendix B from the applicant's consultant, Ford, Bacon & Davis, describing its SULFTEN System which was not incorporated into the air quality evaluation because of insufficient time. The SULFTEN System could greatly reduce the emission of sulfur dioxide from that evaluated in this EIS.

Carbon monoxide (CO) standards are 40 mg/m^3 (1-hr average) and 10 mg/m^3 (8 hr average). Maximum estimated impact from the facility is 0.027 mg/m^3 (1-hr average) and 0.024 mg/m^3 (8-hr average). The proposed facility's CO impacts are not expected to significantly influence CO concentrations in the area. Estimated CO impact from increased vehicle trips is approximately 0.6 mg/m^3, which would be added to the estimated existing concentration of of 1.7 mg/m^3 (1-hr average). Emissions from vehicles are and will continue to be the dominant source of ground level carbon monoxide.

The estimated maximum NO_x concentration from the existing sources is 2.3 $\mu g/m^3$. The estimated maximum NO_x concentration from the proposed facility is 5.0 $\mu g/m^3$. The cumulative NO_x impact is thus 7.3 $\mu g/m^3$, which is well below the 100 $\mu g/m^3$ standard. Nitrogen oxide is also emitted from vehicles. The cumulative industrial and motor vehicle NO_x impact is expected to be below the 100 $\mu g/m^3$ annual average standard.

The estimated emissions of hydrocarbons from the proposed facility are 1,888 metric tons/year (2,080 tons/year). This would be four times more hydrocarbons than are currently emitted by existing sources. These emissions may cause violations to the ambient standard of 160 $\mu g/m^3$ (3-hr average). Violations of the hydrocarbon stan-play in ozone formation. However, an air quality analysis based on specific process emissions and final design must show that all air quality standards will be met and no remaining allowable increment will be exceeded before the required air quality permit can be obtained from DHEC.

(4) Unavoidable Adverse Air Quality Impacts

The analysis concludes that unavoidable adverse air quality impacts would result from fugitive construction emissions, fugitive hydrocarbon emissions and sulfur dioxide emissions.

Adverse impacts from construction activities include particulate emissions and pollutants associated with vehicle exhaust. A number of mitigative procedures are available to reduce these impacts; some of these methods are discussed in Section VII.A.1.

The adverse impacts resulting from hydrocarbon emissions during plant operations can be reduced through a strict preventive and corrective maintenance program. As part of these programs, monitoring of operations and air quality can be conducted to ensure that all leaks are identified so that repairs can be made.

The main source of sulfur dioxide emissions from the proposed refinery is the exhaust gases vented from the Claus-Stratford Tail Gas Treating and Sulfur Recovery Unit. Although this recovery unit is efficient for the removal of sulfur from process gases, the exhaust gases can have high concentrations of SO_2. If these exhaust gases are vented through a stack that has relatively poor dispersive properties, ground level concentrations of pollutants can be high. Ground level concentrations can be reduced through various design considerations such as combining exhaust gases and venting through one stack. A possible means of greatly reducing sulfur dioxide emissions is the SULFTEN System described in the letter dated 15 May 1984 in Appendix B from Ford, Bacon & Davis.

B. Water Quality

1. Effects of Refinery and Pipeline Construction

a. Types of Construction. Construction activities associated with the proposed CRDC refinery include:

- installation of oil pipelines through upland areas, across the Sampit River and through wetlands adjacent to the Sampit River;
- construction at the selected refinery site (the preferred site, Harmony Plantation, borders both the Sampit River and Turkey Creek, while the Myrtle Grove site is approximately 2,010 m [6,600 ft] east of the Harmony site [Figure V.A-1]);
- installation of sewer and water pipelines and electricity transmission lines.

It is assumed that no construction is needed at or adjacent to the South Carolina State Ports Authority pier, with the exception of the oil pipelines.

Pipeline construction procedures are basically quite similar for construction in upland areas, wetland areas and stream crossings. The basic steps for pipeline construction, in chronological order, are as follows:

- construction of storage facilities, pumping stations and control facilities as needed;
- surveying and staking of pipeline right-of-way;
- clearing and grading of land for equipment as well as pipeline;
- construction of storm-water diversion trenches;
- stringing of pipe before or after ditch is dug (trenching and pipeline supply may involve the efforts of two different contractors);
- trenching and temporary deposition of disturbed soil;
- welding, bending, cleaning, coating and wrapping (for a stream crossing, concrete coating and collars are often utilized for added stability);
- pipelaying into trench;
- backfilling and cleanup including revegetation and properly disposing of unused materials;
- pipeline testing for leaks with discharging testing fluids;
- pipeline maintenance - block valves to close portions of pipeline for repair, pipeline scrapers for internal cleaning that are released and captured in traps, right-of-way (ROW) inspections, ROW maintenance and clearing (usually 15 m [50 ft] width).

Two 30-centimeter (12-inch) diameter pipelines have been proposed to transport crude oil from the state pier to the proposed refinery. Two basic methods are available for installing pipeline within a wetland area. The "push" method causes less disturbance of wetland area than the floatation method, but the "push" method can only be used if the wetland soil is firm enough to support a dragline or a buggy-mounted backhoe. With the "push" method, a water-filled ditch 1.2 to 1.8 m (four to six ft) deep and 2.4 to 3 m (eight to 10 ft) wide is excavated (Conner et al., 1976) and the spoil is placed on one or both sides of the ditch. The pipe sections are joined and then pushed into the ditch with floats attached. With the floatation method, a 12 to 15 m (40 to 50 ft) wide canal is excavated 1.8 to 2.7 m (six to 9 ft) deep by a barge-mounted dredge to provide access for the pipe-laying barges. A smaller, deeper trench is dredged at the bottom of the canal for pipe placement. The pipe sections are connected on a series of pipe-laying barges and then lowered into the pipe trench.

It is proposed that the Sampit River crossing be a trench-type installation, 183 m (600 ft) in length (USEPA, 1983) with an easement width of 30 m (100 ft) (SC Coastal Council, 1981). The most recently prescribed location for the river crossing is 152 m (500 ft) upstream of the U.S. Highway 17 bridge. Pipeline depth is specified to be 10.6 m (35 ft) below mean low water elevation or 3 m (10 ft) below the river bottom, whichever is deeper (USACoE, 1983).

To install pipeline at a river crossing, a bucket dredge or a hydraulic dredge can be utilized. With bucket dredging, the dredged spoil material would be placed underwater alongside the trench; with hydraulic dredging, spoil could be placed underwater alongside the trench or in spoil piles near the river bank.

The trench may remain open for one to eight months. The average time needed for underwater pipeline installation is two to three weeks per mile of pipeline installed. Following installation, the pipelines would be hydrostatically tested before the trench is backfilled.

Two other forms of pipeline installation are possible for the river crossing. These are above-water connection to the new U.S. Highway 17 bridge (or another future bridge) and tunneling beneath the river. Additional pumping energy would be needed if the pipe were to be connected to the new U.S. Highway 17 bridge. For horizontal drilling, a rig would be set up on one side of the river for the drilling equipment, and a dike would be needed to control drilled debris once the pipeline reached the opposite side of the river. A horizontal distance of approximately 1,372 m (4,500 ft) is considered to be the limit of tunneling technology (Lydecker, 1983), thus the Sampit River crossing of 183 m (600 ft) is well within the present state-of-the-art.

Refinery construction activities include timber clearing, grubbing, grading, concrete and asphalt placement, building and road construction, equipment and pipeline installation, soil stabilization and revegetation. Road access to the refinery is also required. Runoff and wastewater management, traffic control and pest control are activities that take place while construction is ongoing and after construction is completed.

According to Davis and Floyd, Inc. and Arthur D. Little, Inc. (1983a), CRDC intends to purchase 60.7 ha (150 ac) and initially develop 16 ha (40 ac) of the purchased land. The refinery would include a crude oil distillation column, a delayed-coking unit and a system for removal of hydrogen sulfide and sulfur dioxide, a

kerosene hydrogen facility, a naphtha hydrogen treating unit and a catalytic reformer. Petroleum storage facilities presumably would be installed as well as a tanker-truck loading platform. Road access, water pipelines and either above-ground or underground transmission of electricity to the site also would be required in addition to wastewater treatment and liquid waste storage facilities. The proposed runoff and wastewater management facilities are specified in Section VII.B.2.

b. Chemical and Hydrocarbon Pollutants. Discharges that can occur during construction activities are runoff during and after storm events, releases of sediment due to pipeline river crossing (trenching or tunneling method), sanitary wastewaters, and leaks or spills of equipment lubricants and fuels. On-site storage and treatment facilities can control each of these types of discharges to varying degrees.

The quantity and quality of these discharges can vary according to many factors. These factors are summarized in Table VII.B-1. All of these parameters, which alter the quantity or quality of the various discharges, combine to make quantitative predictions of pollutant discharges impossible until the locations and methods for construction are specified. After locations and methods are specified, topographic maps, recent aerial photographs, the county soil survey and representative storm hydrographs can be utilized to estimate runoff characteristics. For a forested area, runoff quantities resulting from a five-centimeter (two-inch) rainfall can range from 0 to approximately 1.5 cm (0 to 0.6 in). Silt is the basic soil type that is most highly erodable.

c. Impacts of Construction on Hydrology and Water Quality. Construction activities affect water and sediment flow. These activities and their impacts are summarized in Table VII.B-2. Relative to trenching a path for pipelines through the bottom of a tidal river, impacts can vary depending upon sediment characteristics, water velocities in the river and installation methods. Dredged spoil may need to be placed on shore, rather than underwater alongside the trench, to avoid refilling of the trench due to tidal velocities. Turbidity increases near the trench can be anticipated as a result of trenching and refilling of the trench following pipeline installation. If spoil is placed alongside the trench, turbidity in the water column can be generated as long as the trench is uncovered. If spoil is placed on shore, runoff from the spoil piles can affect water quality.

River crossing impacts resulting from the tunneling method or bridging method of installation are less numerous and very likely less adverse than if the trenching method is utilized.

The impacts of all construction activities on the flow of water and sediment will last beyond the construction period. For the proposed river crossing, pre-construction conditions can be achieved relatively quickly with suitable regrading of the river bottom. For upland and wetland areas, regeneration of pre-construction conditions can take many years, depending upon the type and age of vegetation disturbed during construction. For the refinery, pre-construction conditions would not be regenerated following construction because the refinery and related facilities, road access, and developed periphery areas would exist. Furthermore, even for the proposed river crossing, certain water quality transformations and sediment movement may not be quickly reversible to pre-construction conditions downstream of the river crossing. As sediments are resuspended, dissolved oxygen levels in the water column can decline and nutrient and organic concentrations in the water column can increase, depending upon water circulation and water-sediment chemistry and biology conditions at the time of dredging. Water

TABLE VII.B-1

SUMMARY OF POLLUTANTS RESULTING FROM CONSTRUCTION ACTIVITY

Source of pollutant	Factors affecting pollutant characteristics
Runoff	Rainfall intensity and duration
	Soil moisture prior to rainfall
	Exact placement of refinery: soil type, drainage, pathways, topography
	Effectiveness of stormwater storage and treatment
	Vegetation cover
	Time of year; the most erosive rainfalls occur during July and August in southeastern Atlantic coastal states (Novotny and Chesters, 1981)
Sediment resulting from pipeline river crossing (trenching or tunneling)	Water velocities within the Sampit River (trenching)
	Effectiveness of storing drilling muds (tunneling)
	Sediment particle size and cohesive properties
Sanitary wastewaters	Effectiveness of wastewater management methods
	Soil characteristics if wastewater is to be disposed of at the site
Leaks or spills	Effectiveness of runoff control (see factors affecting runoff discharge above)
	Effectiveness of equipment maintenance and spill control measures
	Extent of liquid transfer activities to be conducted on the refinery site

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TABLE VII.B-2

SUMMARY OF CONSTRUCTION IMPACTS ON WATER AND SEDIMENT FLOW

Activity	Impact on flow of water and sediment
Pipeline river crossing using trenching method	Increased turbidity near pipeline crossing (depending upon sediment type, sediment cohesiveness and water velocities)
	Temporary destruction or disturbance of vegetation and aquatic habitat in Sampit River near mouth
	Temporary change in local water velocities and salinities adjacent to pipeline crossing
	Temporary alteration of runoff flow to Sampit River at pipeline crossing due to temporary spoil piles near river bank
Pipeline river crossing using tunneling method	Temporary alteration of runoff flow to Sampit River near surface location for tunneling activity due to transfer of drilling muds during tunneling activities
	Possible temporary increase in turbidity within the Sampit River near drilling mud storage location
Pipeline river crossing using existing bridge	No discernible impacts
Pipeline installation in upland and wetland areas	Alteration of runoff flow paths intersecting pipeline route
	Higher levels of suspended solids and compounds attached to these solids reaching waters downstream of pipeline. (depending upon topography, soil type, soil moisture content and erosion control practices during and following pipeline installation)
	Short-term destruction, at a minimum, of vegetation and associated wildlife habitat

TABLE VII.B-2
(continued)
SUMMARY OF CONSTRUCTION IMPACTS ON WATER AND SEDIMENT FLOW

Activity	Impact on flow of water and sediment
Refinery construction	Alteration of runoff flow quantities and paths Possibly higher levels of suspended solids, compounds attached to these solids, sanitary wastewaters and spilled materials reaching downstream water bodies

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quality conditions may be altered for a considerable time in waters with slow flushing characteristics such as the Sampit River.

Impacts on water quality resulting from pipeline and refinery construction are summarized in Table VII.B-3. Most of these impacts are associated with either runoff flows or sediment disruption at the proposed river crossing. Various pollutants can become associated with sediments and possibly be dissolved when mixed with any water column. The magnitudes of these impacts depend upon a myriad of factors that vary as a function of time and/or location. These include: runoff intensity and duration; chemical nature of pollutant and ease with which pollutant can be transported in a suspended or dissolved state; water velocities, water depths and water quality within Turkey Creek, the Sampit River and Winyah Bay without the proposed project; sediment quantities and characteristics; availability of pollutants based on runoff control measures and also based on upland soil and vegetation. The impacts of these pollutants on aquatic ecology are discussed elsewhere.

Dredging of wetland soils containing high levels of organics could result in the release of higher quantities of oxygen-demanding substances than dredging of river bottom or upland soils. Conversely, runoff water velocities are often lower in wetland areas than in upland areas; lower runoff water velocities generally discourage the release of pollutants bound to sediments.

Based on field assessments of impacts from dredging in coastal waters of Alabama, varying degrees of impacts on water quality have been observed (USEPA et al., 1973). Increased turbidity was reported, but the extent of the increase varied. Dissolved oxygen levels declined at one location as a result of channel dredging and did not significantly change at another location. Dredging did not alter total nitrate or total phosphorus levels at one location while, at other locations, significant leaching of ammonia and Kjeldahl nitrogen was observed (Barry Vittor and Associates, 1978). Clearly impacts can vary from location to location and also as a function of time.

Because the pipeline river crossing basically would be perpendicular to tidal currents, salinity concentrations are not expected to be altered as a result of pipeline construction, except perhaps at the crossing itself. Documented cases of dredging affecting salinity concentrations are primarily associated with deep navigation channels dredged parallel to tidal currents.

d. Mitigative Measures. Ways to reduce the adverse impacts of construction activities are available. A number of mitigative measures are presented in this section in the form of industry practices. Methods regulatory agencies can utilize to promote or require implementation of proposed industrial practices are not discussed.

Existing erosion and runoff control measures for controlling impacts of construction in upland areas are listed below:

- sedimentation basin(s) with flow diverted to the basin(s), preferrably installed and placed into operation as one of the first site construction steps;
- compacting of soil as soon as possible following soil disturbance;
- use of loose straw, mulch, wood chips, crushed stone, hay bales or vegetation strips 30 to 120 m (98 to 394 ft) in length downstream of construction activites;

TABLE VII.B-3

POSSIBLE WATER QUALITY IMPACTS ASSOCIATED DIRECTLY WITH SPECIFIED POLLUTANTS DUE TO PIPELINE AND REFINERY CONSTRUCTION

Pollutant	Primary sources	Possible water quality impacts
Sediment	Clearing large areas at one time	Altered flow paths and possible filling in of Turkey Creek
	Lack of planned grading	Increased flood flows due to clearing of site
	Too few or improperly implemented erosion control practices	Increased levels of suspended and dissolved solids in the water column.
	Trenching at river crossing and also in upland and wetland areas	Increased movement of other pollutants associated with sediment
Chemicals: Synthetic chemicals; metals; construction chemicals (floating, soluble or adsorbable)	Little sediment control	Increased levels of possibly toxic metals and chemicals in the water column and sediments
	Storage of wastes and equipment on site	
	Spills during construction	
	Bilge from dredging barge, if not controlled	
Nutrients: Nitrogen; phosphorus	Runoff from vegetated area	Increased level of nutrients in water column and sediments with possible resultant decrease in dissolved oxygen
	Sanitary wastes	
	Sediment reaching water column due to pipeline installation	

TABLE VII.B-3
(continued)
POSSIBLE WATER QUALITY IMPACTS ASSOCIATED DIRECTLY WITH
SPECIFIED POLLUTANTS DUE TO PIPELINE AND REFINERY CONSTRUCTION

Pollutant	Primary sources	Possible water quality impacts
Bacteria, viruses, fungi and oyxgen-demanding substances	Improper sanitation	Increase in public health risk
	Insufficient runoff control	Increase in stream oxygen demand resulting in lower dissolved-oxygen levels
	Sediment reaching water column due to pipeline installation	

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- wood chips or crushed stone once construction is completed;
- temporary seeding with fast-growing grass or grain;
- use of sod;
- porous pavement;
- grassed waterways for drainage;
- terracing;
- minimizing extent and time needed for earthwork;
- prohibiting construction during certain times (e.g., the months of July and August when rainfall intensities are high).

The objective of these control measures is to reduce runoff quantities and water velocities, which also results in less leaching of chemical compounds. The extent that any of these measures are to be utilized must be incorporated into the pipeline and refinery design procedures. Regulatory agencies may need to prescribe and enforce particular measures as part of erosion control plans and runoff discharge requirements in order for the measures to be implemented.

Erosion control measures can be reasonably recommended only after the erosion potential at the selected refinery site and along the pipeline route has been evaluated with site specific information and compared to the potential impacts on downstream waters. There are uncertainties in such an evaluation process such as storm characteristics, effects of cohesion among sediment particles, vegetation characteristics as construction begins, non-steady-state conditions during and following storms, and lack of data concerning downstream impacts.

Spills at the proposed refinery can be controlled with a combination of runoff treatment and spill prevention measures. For runoff treatment, sizing of facilities is an important consideration but is not yet available from the applicant. Selection of design storms and estimations of runoff flows are somewhat arbitrary. Flows from any portion of the site from which a spill could originate should be routed to runoff treatment facilities that are operating effectively. Spill prevention measures can be incorporated into the design of the refinery, certified by design inspectors and monitored periodically during utilization. Runoff treatment practices and runoff quality also can be monitored periodically. The preliminary draft discharge permit for the refinery would have required periodic monitoring of certain water quality constitutents. Monitoring at the state dock where tankers will be unloading also may be worthwhile.

Measures to control impacts resulting from pipeline installation in wetland areas and at the proposed Sampit River crossing include:

- taking sediment characteristics into consideration when selecting the final pipeline route;
- utilizing the "push" method for installing pipeline in the wetland area if the wetland soil can support a dragline or backhoe;
- placing spoil in upland areas in such a manner as to minimize alterations in upland runoff patterns (spoil also could be stabilized via compaction and/or vegetation);

- dredging pipeline path through wetland with a barrier plug in place between the dredging operation and the Sampit River;
- using properly operating dredging equipment and trained dredge operators;
- stabilizing the construction site prior to a major storm event;
- avoiding in-water installation activities during the most critical times of the year from an environmental standpoint (e.g., spawning periods or times of intense storms);
- restoring topography and vegetation to pre-construction conditions.

As with other types of possible mitigative measures, costs and any implementation problems need to be evaluated together with the environmental impacts to be controlled before decisions about which measures to implement and how to implement them can be made. Inspection of installation activities and possibly water quality monitoring during installation can help to enforce effective implementation of any measures.

Some mitigative measures to reduce the possibilities of spills from pipelines are:

- preparing and using pipeline operation manual, including system description, pumping controls and procedures, procedures to avoid overflows at refinery, leak detection system, leak contingency plan, and procedures to ensure proper equipment operation;
- enforcing a "no anchorage zone" near pipelines;
- using block valves at regular intervals to shut off flow after a pipe leak is detected;
- clearing debris from river at pipeline crossing when warranted (particularly after a flood period);
- placing marker buoys;
- using preferred pipe material.

2. Effects of Plant Operation

a. Chronic (Continuous) Discharge

(1) Process Waters

(a) Characterization. Wastewaters are continually generated at a refinery as long as the refinery is in operation. The types of wastewaters can include refinery process wastewaters, cooling tower blowdown, boiler and deionizer blowdown, water treating system blowdown, sanitary wastewaters, storm water during and following storm events, and perhaps ballast water from oil tankers docking at Georgetown. Table VII.B-4 lists the types of wastewaters, flows and discharge locations. All types of flows listed above are included except ballast waters from tankers. The sanitary wastewaters and stormwater runoff are discussed in subsequent sections of this report; only the continuous discharges indicated with an asterisk in Table VII.B-4 are discussed in this section.

TABLE VII.B-4

ESTIMATED WASTEWATER FLOWS AND METHODS OF DISCHARGE
FOR THE PROPOSED CRDC REFINERY

Effluent	Estimated flows, in liters (gallons) per day		Locations of discharges
Sanitary waste	14,200	(3,750)	Publicly owned treatment works (POTW)[1]
Oil-free storm water		-[2]	Direct to receiving water body
Oil-free sewer*	1,059,800	(280,000)	Direct to receiving water body
- Boiler blowdown	37,850	(10,000)	
- Cooling tower blowdown (oil free)	654,800	(173,000)	
- Water treating system blowdown	340,650	(90,000)	
- Deionizer blowdown	26,500	(7,000)	
Oil-contaminated sewer[3]	794,850	(210,000)[4]	Pond with baffled outfall to receiving water body
Oil-contamined sewer[5]	3,557,900	(940,000)	API Separator outfall to receiving water body
- Storm water (controlled)	946,250	(250,000)	
- Cooling tower blowdown*	2,611,650	(690,000)	
Process water*	473,125	(125,000)	API Separator, Aeration/Flotation, outfall to receiving water body

*Indicates the effluent is a continuous discharge discussed in this section of the report.

[1]Presumably, POTW refers to the City of Georgetown WWTP.

[2]Uncontrolled runoff.

[3]Uncontrolled; may be contaminated by leakage, spillage, etc. Expected to be short duration with storm events.

[4]Units per hour.

[5]May be contaminated by leakage, spillage, etc.

SOURCE: Taggart, 1983.

Continuously generated solid wastes can include sludges from refinery wastewater treatment units, spent caustic material, ordinary garbage and perhaps sludges from an on-site water treatment plant.

For the proposed Georgetown refinery, sanitary wastewaters are proposed to be routed to a publicly owned treatment works, while other waters are to be discharged from the refinery and eventually will reach Winyah Bay. Oil-free releases are projected to total 1,059,800 liters per day (280,000 gallons per day) in addition to oil-free runoff during and following a storm event. Oil-contaminated releases are projected to total 4,031,000 liters per day (1,065,000 gallons per day) plus uncontrolled discharges. The largest component of the oil-contaminated releases is expected to be blowdown from cooling waters.

Wastewater flow from refinery processes typically include biochemical oxygen demand (BOD), chemical oxygen demand (COD), suspended solids, oil and grease, phenols, ammonia, sulfide and a variety of metals and organic compounds. Wastewater is discharged continuously as long as crude oil is being fed continuously to refinery processes. Wastewater storage facilities can be utilized to regulate wastewater flows entering the wastewater treatment units at a relatively constant rate.

Wastewater flows from boiler, cooling tower, and deionizer blowdown are usually segregated from process wastewater because they do not usually contain the organics associated with process wastewaters. Major parameters of interest include total dissolved solids, chromates, phosphates, temperature and pH (Manning and Snider, 1983). Chromates and phosphates are usually additives to the cooling tower for corrosion and algae control. Additional pollutants may exist in this stream if heat exchanger leaks develop.

According to Davis and Floyd, Inc. and Arthur D. Little, Inc. (1983a), treated Georgetown refinery wastewater is anticipated to total 2,838.8 m^3 (0.75 million gallons) per day with the following pollutant concentrations: five-day biochemical oxygen demand of 10 milligrams per liter (mg/l); chemical oxygen demand, 35 mg/l; total suspended solids, 10 mg/l; oil and grease, 10 mg/l; phenols, 0.02 mg/l; ammonia, 0.5 mg/l; and sulfides, 0.1 mg/l. However, information for typical refinery wastewater, presented by Ford, Bacon and Davis (1982) and shown in Table VII.B-5, reveals higher concentrations of total refinery waste constituents than those presented by the South Carolina State Ports Authority. Part of the apparent discrepancy may be due to the level of wastewater treatment, but the actual cause of this variance is unknown. The concentrations given in Table VII.B-5 for typical refinery wastewater were taken from a refinery where only primary treatment was being used. The applicant proposes a higher level of treatment for process waters, as shown in Table VII.B-4, by the use of aeration and flotation in addition to gravity separation. Due to these additional treatment steps, the typical refinery values are adjusted in subsection VII.B.2.a.(1)(b) below, to provide a better representation of the various components of the process water discharge expected from the proposed CRDC refinery.

Table VII.B-6 identifies metals and organic compounds that are predicted to be generated at the proposed CRDC refinery. An extensive number of organic compounds are expected to be generated, most of which would enter wastewater treatment units at average concentrations less than 0.01 mg/l. Most metals and organic synthetic compounds are undesirable, because they can adversely affect aquatic life forms. Metals are also undesirable in refined oils, so they ar often found in heavy distillate residuals, liquid wastes, and solid wastes chelated with hydrocarbons.

Solid wastes may impact surface water quality if runoff and leachate from an approved off-site landfill facility cannot be controlled, for example, in a storm event that exceeds its design capacity. Continuously generated solid wastes from the proposed CRDC refinery can be expected to include:

TABLE VII.B-5

CHARACTERIZATION OF TYPICAL REFINERY WASTEWATERS*

IN-PLANT LEVELS	
Boiler blowdown	
Total dissolved solids	2,500
Total suspended solids	150
Alkalinity	500
Temperature	200
Cooling tower blowdown	
Typical	
Hardness	600**
Alkalinity	50
Sulfates	500
In oil-contaminated cooling water	
Oils	30
Temperature	90
Deionizer blowdown and rinse	
Total dissolved solids	10,000
pH	3-10
Temperature	90
Process water	
Total suspended solids	200
Oils	100
Sulfides	2
Phenols	5
Phosphates	20
Chlorides	250
Ammonia	10
Chemical Oxygen Demand	1,700
Temperature	110
DISCHARGE LEVELS	
Typical total refinery wastewater (excluding sanitary)	
Primary treatment only	
Biochemical oxygen demand	109
Chemical oxygen demand	314
Oils	76
Phenols	5.7
Sulfides	7.2
Ammonia	32

*All values are in units of milligrams per liter, except temperature in °F and pH.

**5-6 times freshwater hardness

SOURCE: Taggart, 1983.

TABLE VII.B-6

ESTIMATED METALLIC AND ORGANIC POLLUTANT DISCHARGES FOR THE PROPOSED CRDC REFINERY, GEORGETOWN, SC

Pollutant believed to be present	Pollutant Concentration (mg/l)		
	Daily maximum	30-day maximum	Long-term average
Metals, Cyanide and Phenols			
Copper, total	0.2	0.05	<0.05
Chromium, total	1.7	0.3	<0.1
Cyanide, total	0.1	<0.05	<0.01
Mercury, total	0.06	<0.01	<0.001
Phenols, total	0.1	<0.05	<0.01
Zinc, total	1.1	0.2	<0.1
GC/MS Fraction - Volatile Compounds			
Benzene	0.01	<0.01	<0.01
Ethylbenzene	<0.01	<0.01	<0.01
Methylene Chloride	0.1	0.05	<0.02
1,1,2,2-Tetrachloroethane	<0.01	<0.01	<0.01
Tetrachloroethylene	<0.01	<0.01	<0.01
Toluene	0.03	<0.01	<0.01
1,2-Trans-Dichloroethylene	<0.01	<0.01	<0.01
Trichloroethylene	<0.01	<0.01	<0.01
GC/MS Fraction - Acid Compounds			
2,4-Dimethylphenol	<0.01	<0.01	--
4-Nitrophenol	<0.01	<0.01	<0.01
p-Chloro-m-Cresol	<0.01	<0.01	<0.01
Phenol	<0.1	<0.05	<0.02
GC/MS Fraction - Base/Neutral Compounds			
Anthracene	0.001	<0.001	<0.001
Benzo(a)Pyrene	0.005	<0.001	<0.001
Bis(2-Ethyl-hexyl) Phthalate	2	<0.01	<0.01
Chrysene	0.05	<0.01	<0.01
Diethyl Phthalate	0.03	<0.01	<0.01
Naphthalene	0.001	<0.001	<0.001
Phenanthrene	0.001	<0.001	<0.001
Pyrene	0.01	<0.01	<0.01

TABLE VII.B-6
(continued)
ESTMATED METALLIC AND ORGANIC POLLUTANT DISCHARGES FOR THE
PROPOSED CRDC REFINERY, GEORGETOWN, SC

Pollutant believed to be present	Pollutant Concentration (mg/l)		
	Daily maximum	30-day maximum	Long-term average
GC/MS Fraction - Pesticides			
PCB-1221	<0.01	<0.01	<0.01
PCB-1232	<0.01	<0.01	<0.01
PCB-1248	<0.01	<0.01	<0.01
PCB-1260	<0.01	<0.01	<0.01
PCB-1016	<0.01	<0.01	<0.01

SOURCE: Davis and Floyd, Inc., 1981.

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- coking unit wastes (coke fines and spilled coke at unloading areas);
- spent catalyst and catalyst fines from catalyst regenerators;
- waste sludges from processing;
- slop oil (disposed of as solid wastes).

Wastewater treatment yields a wide variety of solids and emulsions requiring disposal. Settled sludges from storage tanks and pipelines can include metals, sulfides, sand and oil, but tank and pipeline cleanouts are usually conducted only once every few years. Most of the constituents of sludge-processing wastes such as phenols, benzene and heavy metals are considered hazardous and require state-approved storage, treatment and disposal practices. Any of the wastewater pollutants listed in Table VII.B-6 that can combine with solid particles can be part of the generated solid wastes. Crude oil heavy metal content largely dictates heavy metal content in the sludge. Hazardous waste disposal is regulated by the Federal Resource Conservation and Recovery Act (RCRA) and is discussed in Section VI.C.2.b of this document.

(b) Estimated Concentrations, Water Quality Standards and Fate Characterization for Effluent Components. The characterization of "typical total refinery wastewater (excluding sanitary)" given in Table VII. B-5 and the "estimated wastewater flow" given in Table VII.B-4 are used here as a basis to calculate the estimated quantities of these constituents that would be released in the process water discharge from the proposed CRDC refinery. These calculations were made with input supplied by the consultant for the proposed CRDC refinery (Taggart, personal communication, 1983). The typical refinery data were taken from an operational 45,000 barrel-per-day refinery having a gross flow rate of 3,028 liters (800 gallons) per minute, as reported by Beychok (1967).

Several adjustments to the values given for process water component concentrations, however, are considered appropriate to arrive at reasonable estimates for the proposed refinery. The typical refinery effluent was treated only by gravity separation, whereas the proposed refinery process water will be further treated by aeration and flotation. To calculate appropriate reductions to effluent concentrations that would result from this additional treatment, several sources of data (from both pilot plants and operational refineries) on the efficiency of secondary treatment by aeration and flotation were used. These data were compiled by the American Petroleum Institute (1969) and the Gulf Publishing Company (1968). Table VII.B-7 incorporates these factors to provide new estimates for the major constituents that specifically relate to the proposed refinery process wastewater. Since the concentrations given in Table VII.B-5 were in the total refinery wastewater (excluding sanitary), the corresponding volume from Table VII.B-4 (4,144,575 lpd) was used to calculate total continuous pollutant additions from process water to the Sampit River in terms of kilograms per day.

The refinery blowdown waters are proposed to be handled in two ways. The non-oil contaminated portion will be discharged directly to the receiving waters. The total volume of this flow is estimated to be 1,059,800 liters (280,000 gallons) per day. The mass discharge of components from this source is shown in Table VII.B-7. The oil contaminated cooling water will be routed through an API separator prior to discharge. Total expected volume of this wastewater will be 2,611,650 liters

TABLE VII.B-7

DERIVATION OF ESTIMATED COUNTINUOUS DISCHARGE EFFLUENT
COMPONENT VALUES FOR PROPOSED CRDC REFINERY
GEORGETOWN, SC

PROCESS WATER

Component	Primary treatment conc. (mg/l) from Table VII.B-5*	Mass discharge (kg/day)	Aeration and flotation range of reduction values (%)	Average	Adjusted mass discharge (kg/day)
BOD	109	452	80[2]	80	90
COD	314	1301	70[2],80[2]	75	325
Oil	58.5	242	79[1],83[1],90[2]	84	39
Phenol	5.7	24	94[2],100[2]	97	1
Sulfide	7.2	30	83[1]	83	5
Ammonia	32	133	30[2]	30	93

OIL CONTAMINATED BLOWDOWN**

Component	Concentration (mg/l)	API Separator effluent Conc.[3] (mg/l)	Mass Discharge (kg/day)
Oil	30	30	78.3

OIL-FREE BLOWDOWN***

Component	Concentration (mg/l)	Mass discharge (kg/day) by source	Mass discharge (kg/day) total
Total dissolved solids	boiler - 2,500 deionizer - 10,000	94.6 265.0	359.6
Total suspended solids	boiler - 150		5.6
Sulfates	cooling tower - 500		327.4

[1] Gulf Publishing Company, 1962.

[2] API, 1969.

[3] Apparent lower limit of oil in effluent from API separator under excellent operating conditions is 50 mg/l (Manning and Snider, 1983). Therefore, no reduction in oil by API separation is assumed.

*Oil from cooling tower blowdown has been excluded. Remaining values are treated as process water components diluted in a total continuous refinery discharge, i.e., in this case, 4,144,575 lpd (1,095,000 gpd).

**2,611,650 lpd (690,000 gpd)

***Boiler - 37,850 lpd (10,000 gpd); Cooling Tower - 654,800 lpd (173,000 gpd); Deionizer - 26,500 lpd (7,000 gpd)

TABLE VII.B-8

CALCULATION OF THE PROCESS CONFIGURATION
FOR THE PROPOSED CRDC REFINERY

Process category	Processes included	Weighting factor
Crude	Atm. crude distillation Desalting	1
Cracking and coking	Hydrotreatment Delayed coking	6

Process	Capacity (1000 bbl per stream day)	Capacity relative to throughput	Weighting factor	Processing configuration
Crude				
Atm.	30.0	1.0		
Desalt.	30.0	1.0		
Total		2.0	X1	2.0
Cracking/coking				
Hydro.	22.3	0.743		
Coking	7.0	0.233		
Total		0.976	X6	5.86
Refinery process configuration				7.86

SOURCE: Format - Federal Register, 1982.

Process data - Taggart, personal communication, 1984; Cathcart, 1982.

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(690,000 gallons) per day. The mass discharge of oil from this source is also shown in Table VII.B-7. Concentrations of other components, such as additives for corrosion and algae growth inhibition that may be in these effluent streams, would depend upon operational conditions and therefore cannot be estimated, but are expected to be relatively low.

These estimated discharge rates of chronic refinery pollutants are compared below with Effluent Limitations Guidelines mandated by 40 CFR Part 419 (47 FR 46434-46457), entitled "Petroleum Refining Point Source Category Effluent Limitations Guidelines, Pretreatment Standards, and New Source Performance Standards" (Federal Register, 1982). The process configuration of the proposed refinery (Table VII.B-8) is presented to describe the calculations performed to determine the specific limitations applicable to the design and capacity of the proposed Georgetown refinery. The calculated refinery process configuration is used to obtain the process factor, which, together with the size factor, is applied in Subpart B-Cracking Subcategory (40 CFR Part 419.20) to calculate the specific Effluent Limitations Guidelines for the proposed refinery. The three sets of guidelines applicable to the proposed refinery, based on 1) Best Practical Control Technology (BPT), 2) Best Available Technology (BAT) and 3) New Source Performance Standards (NSPS), are presented in Table VII.B-9. From the table it can be seen that the NSPS limitations are more stringent for every major pollutant except ammonia, for which the BPT limitation is only slightly lower. Since the most restrictive limitation is the dominating regulatory control for each refinery effluent constituent at the point of discharge, these are presented in Table VII.B-10 along with Water Quality Criteria (USEPA, 1980) and compared with the estimated constituent concentrations and loadings from Tables VII.B-6 and VII.B-7. (It should be noted that the calculations given for the USEPA Effluent Limitations Guidelines are estimates since the refinery design data, upon which they were based, have not been finalized. The NPDES permit would require compliance with the final New Source Performance Standards. The Water Quality Criteria refer to ambient water concentrations and, thus, are not directly comparable to the values for discharge loadings or concentrations.) Table VII.B-10 also presents a brief characterization of environmental fate of the various effluent constituents.

Most of the metals and organic pollutants anticipated in the discharge from the proposed refinery (see Table VII.B-6) have been excluded from regulation under the petroleum refining point source category (40 CFR Part 419, 47 FR 46434-46457). The following list includes those priority pollutants expected in the proposed refinery effluent that have been excluded from national regulation because they were not detected in effluents from BPT (best practical control technology currently available) treatment systems by Section 304 (h) (PL 92-500 et seq.) analytical methods or other state-of-the-art methods (40 CFR Part 419, Appendix A):

1,1,2,2-tetrachloroethane
1,2-trans-dichloroethylene
2,4-dimethylphenol
ethylbenzene
naphthalene
4-nitrophenol
phenol
anthracene
tetrachloroethylene

TABLE VII.B-9

EFFLUENT LIMITATIONS FOR THE PROPOSED CRDC REFINERY[1,2]

Pollutant or pollutant property	BPT[3] Effluent limitations		BAT[4] Effluent limitations		NSPS[5] Effluent limitations	
	Maximum for any one day	Average of daily values for 30 consecutive days	Maximum for any one day	Average of daily values for 30 consecutive days	Maximum for any one day	Average of daily values for 30 consecutive days
BOD_5	130.2	99.7	N/A[6]	N/A	104.1	55.6
TSS	124.6	80.5	N/A	N/A	72.2	46.0
COD	1,341.8	696.4	1,341.8	696.4	754.0	389.8
Oil and grease	53.7	28.8	N/A	N/A	30.7	16.6
Phenolic compounds	1.34	0.64	1.34	0.64	0.76	0.37
Ammonia as N	120.1	54.3	120.1	54.3	120.1	54.9
Sulfide	1.15	0.52	1.15	0.52	0.67	0.31
Total chromium	2.74	1.60	2.74	1.60	1.53	0.89
Hexavalent chromium	0.224	0.102	0.224	0.102	0.128	0.056
pH	6.0 to 9.0	6.0 to 9.0	N/A	N/A	6.0 to 9.0	6.0 to 9.0

[1] 40 CFR Part 419 (47 FR 46434), Petroleum Refining Point Source Category Effluent Limitations Guidelines, Pretreatment Standards, and New Source Performance Standards, Final Rule, Subpart B - Cracking Subcategory.

[2] Units given are kilograms applicable to a 30,000 barrel per stream day throughput.

[3] BPT = Best Practical Control Technology Currently Available.

[4] BAT = Best Available Technology Economically Achievable.

[5] NSPS = New Source Performance Standards.

[6] N/A = not applicable: these pollutants or pollutant properties are not regulated by final BAT limitations.

TABLE VII.B-10

ESTIMATED PROCESS WATER COMPONENTS, REGULATORY STANDARDS AND [illegible]ERIA, AND FATE CHARACTERIZATION

Component	Estimated Effluent Loadings[1]/Concentration[2]	Estimated Effluent Limitations[3] Water Quality Criteria	Fate Characterization[8]
BOD_5	90 kg/d[1]	NSPS: 104.1[5]/55.6 kg[6]	
TSS	157 kg/d[4]	NSPS: 72.2/46.0 kg	
COD	325 kg/d	NSPS: 754.0/389.8 kg	
Oil and grease	117.3 kg/d	NSPS: 30.7/16.6 kg	Aromatic fractions are generally readily degradable but major concern for toxic effects; heavier distillation fractions, generally nontoxic, will incorporate in sediments and persist indefinitely in anoxic conditions.
Phenol	1 kg/d	NSPS[7]: 0.76/0.37 kg HH: 300 µg/l O 3.5 mg/l T	Degradable; chlorination may produce dichlorophenols that are more toxic, bioaccumulative and associate with suspended matter and bottom sediments.
Ammonia as N	93 kg/d	BAT: 120.1/54.3 kg	Toxic in unionized form but not persistent; oxidizes readily to nitrite.
Sulfide/sulfate	332.4 kg/d	NSPS: 0.67/0.31 kg	Toxic but short-lived; oxidizes quickly to sulfate but may result in high BOD.
Chromium	1.7/0.3 mg/l[2] (0.80/0.14 kg/d)	Total NSPS: 1.53/0.89 kg Hexavalent NSPS: 0.128/0.056 kg FW: 0.29 µg/l 24 hr 21 µg/l max SW: 18 µg/l 24 hr 1.26 mg/l max HH: 50 µg/l T Trivalent FW: 2.2 mg/l max HH: 170 mg/l T	Tends to remain in solution and disperse with water flow; Cr^{3+} ion forms stable complexes in acidic waters that hydrolize in normal or alkaline waters; toxicity generally associated with Cr^{6+} form; bioaccumulative; persistent.
Copper	0.2/0.05 mg/l	FW: 5.6 µg/l 24 hr 12 µg/l max SW: 4 µg/l 24 hr 23 µg/l max HH: 1.0 mg/l O	Dominant species are $Cu(OH)_2$, $CuCO_3$ and Cu^{2+}, equilibrium varies with pH and presence of organic liquids; ionic form more soluble in low pH, acidic waters, less soluble in high pH, alkaline waters; forms complexes and adsorbs to clays, sediments and organic particulates; highly toxic, persistent.
Cyanide	0.1/<0.05 mg/l	FW: 3.5 µg/l 24 hr 52 µg/l max HH: 200 µg/l T	The free-cyanide forms, HCN and CN^-, are strong uncouplers and the most toxic species; the alkali metal salts readily hydrolize to form HCN; CN^- can combine with heavy metal ions to form metallocyanide complex anions of variable stability and relatively low toxicity; persistence is dependent upon conditions of light, temperature and pH; HCN can be derived from cyanide complexes by ionization, dissociation and photo decomposition.
Mercury	0.06/<0.01 mg/l	FW: 0.2 µg/l 24 hr 4.1 µg/l max SW: 0.1 µg/l 24 hr 3.7 µg/l max HH:O 144 µg/l T	Insoluble, bioaccumulative and persistent; incorporates in bottom sediments; oxidizes in sediments to divalent mercury, then converted by both aerobic and anaerobic bacteria to highly toxic methyl or dimethyl mercury capable of food-web proliferation.

TABLE VII.B-10
(continued)
ESTIMATED PROCESS WATER COMPONENTS, REGULATORY STANDARDS AND CRITERIA, AND FATE CHARACTERIZATION

Component	Estimated Effluent Loadings[1]/Concentration[2]	Estimated Effluent Limitations[3] Water Quality Criteria	Fate Characterization[8]
Zinc	1.1/0.2 mg/l	FW: 47 μg/l 24 hr 180 μg/l max SW: 58 μg/l 24 hr 170 μg/l max HH: 5.0 mg/l O	Insoluble, persistent; incorporates in bottom sediments; toxic but not bioaccumulative.
Benzene	0.01/<0.01 mg/l	HH: 6.6 μg/l C	These compounds are all highly soluble but none are persistent in water due to high volatility; will not be found in sediments due to high solubility; all are mildly toxic, ethylbenzene and toluene are readily degradable; methylene chloride is converted to carbon monoxide in water and evolved with phosgene, a highly toxic gas, being produced as an intermediate product; chlorinated ethanes form azeotropes with water which could influence persistence; in general, air quality is of greater concern than water quality.
Ethylbenzene	<0.01/<0.01 mg/l	HH: 1.4 mg/l T	
Methylene chloride	0.1/0.05 mg/l	HH: 1.9 μg/l C	
1,1,2,2-Tetrachloroethane	<0.01/<0.01 mg/l	HH: 1.7 μg/l C	
Tetrachloroethylene	<0.01/<0.01 mg/l	HH: 8 μg/l C	
Toluene	0.03/<0.01 mg/l	HH: 14.3 μg/l T	
1,2-Trans-dichloroethylene	<0.01/<0.01 mg/l	none	
Trichloroethylene	<0.01/<0.01 mg/l	HH: 27 μg/l C	
2,4-Dimethylphenol	<0.01/<0.01 mg/l	HH: 400 μg/l O	These phenolic componds biodegrade readily with a half-life of a few weeks; toxicity is generally mild, effects generally reversible; if chlorinated, persistence and toxicity increase markedly.
4-Nitrophenol	<0.01/<0.01 mg/l	none	
p-Chloro-m-cresol	<0.01/<0.01 mg/l	HH: 3.0 mg/l O	
Anthracene	0.001/<0.001 mg/l	HH:0.028 μg/l C	Low toxicity but potential to bioaccumulate; undergoes direct photolysis and rapid microbial transformation; non-carcinogenic and non-mutagenic.
Benzo (a) pyrene	0.005/<0.001 mg/l	HH:0.028 μg/l C	Practically insoluble in water; non-degradable; strongly adsorbs onto suspended material and incorporated into sediments; no direct toxicity but bioaccumulates and is potent carcinogen.
Bis (2-ethylhexyl) phthalate	2.0/<0.01 mg/l	HH: 15.0 mg/l T	Insoluble in water; adsorbs onto suspended material and sediments; degrades slowly; low toxicity; will not bioaccumulate; due to two ester groups, it is hydrolized and excreted by fish.
Chrysene	0.05/<0.01 mg/l	HH:0.028 μg/l C	Insoluble in water; adsorbs onto suspended material and sediments; persistent; non-carcinogenic
Diethyl phthalate	0.03/<0.01 mg/l	HH: 350 mg/l T	Insoluble in water; subject to metabolic activity and is relatively short-lived; will not bioaccumulate.
Naphthalene	0.001/<0.001 mg/l	HH:0.028 μg/l C	Insoluble in water; fate similar to anthracene but less bioaccumulative.

TABLE VII.B-10
(continued)
ESTIMATED PROCESS WATER COMPONENTS, REGULATORY STANDARDS AND CRITERIA, AND FATE CHARACTERIZATION

Component	Estimated Effluent Loadings[1]/Concentration[2]	Estimated Effluent Limitations[3] Water Quality Criteria	Fate Characterization[8]
Phenanthrene	0.001/<0.001 mg/l	HH:0.028 μg/l C	Practically insoluble in water; incorporates into sediments; bioaccumulative; nontoxic; may be carcinogenic.
Pyrene	0.01/<0.01 mg/l	HH:0.028 μg/l C	Insoluble in water; stable; adsorbs onto suspended material and sediments; bioaccumulative; low toxicity but may be carcinogenic.
PCB-1221	<0.01/<0.01 mg/l	FW:0.014 μg/l 24 hr SW: 0.03 μg/l 24 hr HH: 0.00079 μg/l C	PCBs do not readily biodegrade; water is principal sink and transport mechanism; incorporate in sediments; toxic to aquatic organisms in parts per billion or less; highly bioaccumulative, proliferate throughout aquatic ecosystem and concentrate at top of food chains; carcinogenic.
PCB-1232	<0.01/<0.01 mg/l		
PCB-1248	<0.01/<0.01 mg/l		
PCB-1260	<0.01/<0.01 mg/l		
PCB-1016	<0.01/<0.01 mg/l		

[1]Estimated daily value in kilograms per day (kg/d) from derivation in Table VII.B-7. Applicable only to first seven components in this table. All estimates are dependent upon current design information supplied by the applicant.

[2]Estimated maximum daily value followed by maximum 30-day value in milligrams per liter (mg/l) from Davis and Floyd, Inc., 1981. Applicable to all components following the first seven components in this table. Conversions to kilograms per day are provided for chromium for comparison with estimated NSPS values for total chromium.

[3]The calculations given for NSPS and BAT are estimates since the refinery design data, upon which they were based, have not been finalized.

[4]TSS estimate from Raphaelian and Harrison, 1978.

[5]Maximum for any one day in kilograms from most restrictive limitation calculation in Table VII.B-9.

[6]Average of daily values for 30 consecutive days in kilograms from most restrictive limitation calculation in Table VII.B-9.

[7]NSPS Effluent Limitation Guidelines are given for "phenolic compounds."

[8]Sources include: Stecher et al., 1968; Brink, personal communication, 1983; Veith, personal communication, 1983.

LEGEND:
- NSPS = New Source Performance Standards (Federal Register, 1982).
- BAT = Best Available Technology Economically Achievable.
- SW = Aquatic life criteria for saltwater (USEPA, 1980).
- FW = Aquatic life criteria for freshwater (USEPA, 1980).
- HH = Human Health criteria (USEPA, 1980).
- 24 hr = 24 hour average value.
- Max = value not to be exceeded at any time.
- O = Criteria based on organoleptic effect.
- T = Criteria based on toxicity.
- C = Criteria based on carcinogenicity at the 10^{-5} risk level.

trichloroethylene
PCB-1221
PCB-1232
PCB-1248
PCB-1260
PCB-1016

The following list includes those priority pollutants expected in the proposed refinery effluent that have been excluded from national regulation because they are already effectively controlled by technologies upon which other effluent limitations and guidelines are based (40 CFR Part 419, Appendix C):

benzene
parachlorometacresol
diethyl phthalate
chrysene
phenanthrene
pyrene
toluene
mercury
zinc

In addition, the following two expected refinery pollutants are excluded from national regulation because their detection is believed to be attributed to laboratory analysis and sample contamination (40 CFR Part 419, Appendix C):

methylene chloride
bis (2-ethylhexyl) phthalate

Notwithstanding the above exclusions from federal regulation, South Carolina Water Quality Standards require that Water Quality Criteria published by the United States Environmental Protection Agency (USEPA), pursuant to Section 304(a)(1) of Public Law 92-500, be used as a guide in determining levels of toxic wastes which protect water use for establishing standards for Class SC waters (SC Code of Regulations, Chapter 61, Regulation 68, Section D[8]). Class SC waters are defined as "tidal salt waters suitable for secondary contact recreation, crabbing, and fishing, except harvesting of clams, mussels, or oysters for market purposes or human consumption - also suitable for the survival and propagation of marine fauna and flora." The Sampit River from the extent of saltwater intrusion to Winyah Bay and all of Winyah Bay are Class SC waters. The applicable USEPA Water Quality Criteria are given in Table VII.B-10 for most of the priority pollutants excluded from regulation under 40 CFR Part 419.

(c) Impacts to Sediments and Sediment Transport. As indicated earlier, the treated refinery wastewater would include oils and grease, ammonia, sulfides, and phenols, as well as several metals and organic compounds.

Several of the wastewater components are found in natural systems. The decay of organic materials in sediments produces ammonia, phosphate, and carbon dioxide. Sulfate is reduced to sulfide by sulfate-reducing bacteria that occur naturally in sediments. In an estuarine environment such as Winyah Bay, the amount of organic material in fresh sediments can be high, on the level of a few percent, based on

weight of organic carbon. Thus, ammonia, carbon dioxide and sulfide are formed naturally and released into the water column. Therefore the addition of these chemicals could affect water quality, if the levels were high enough, but probably would not impact sediments. Phenol is a water soluble substance that could constitute a water quality threat but, again, probably would not affect sediments.

Oils and greases, by contrast, pose a threat to the sedimentary environment. In a laboratory study (Bassin and Ichiye, 1977), flocculation tendencies of dispersed clay particles and oil emulsions in both freshwater and saltwater were investigated. No flocculation of either clay or oil particles was observed in freshwater. In brackish water (10 ppt salinity), oil alone agglomerated to form a surface slick, but oil with clay rapidly formed large flocs that eventually settled to the bottom. At higher salinities (35 ppt), flocculation of oil and clay, alone, occurred at a faster rate. Therefore, given the range of salinities that would be encountered in Winyah Bay and its tributaries, significant levels of flocculation could be anticipated. Depending on location, the material could either be dredged or remain in place until degrading to background levels over perhaps one to two years. The degradation rate is based on a 1972 blowout spill of crude petroleum (Gannett Fleming, 1983). The actual degradation rate would be expected to vary, depending on the chemical makeup of the oils and greases, estuarine conditions and interactions, and seasonal temperature effects.

Oil and grease released in the proposed refinery wastestream is estimated to be about 117.3 kg/day (Table VI.C-7). Based on the mechanisms listed above, in addition to the normal sinking of heavier fractions, it is probable that a significant amount of oil would be incorporated into the sediments. It should be noted, however, that the NPDES permit would require compliance with the final New Source Performance Standards. Based on present refinery design plans provided by the applicant, the New Source Performance Standard for oil and grease is estimated to be a maximum of 30.7 kg/day.

The persistence of spilled petroleum in estuarine waters has not been well documented, based on references reviewed and communications conducted as part of this EIS. In the case of a south Louisiana crude oil slick, 60 percent of the slick volume was converted by the processes of evaporation, dispersion, dissolution and oxidation, while 25 percent settled to the bottom and was gradually converted by biodegradation over a period of 10 days to one year (U.S. Department of the Interior, 1983).

Persistence and toxicity of spilled materials are perhaps more important than volume in assessing impact severity. For example, a spill of 6,000 barrels of Number 2 refined fuel oil, which is more toxic than crude oil, resulted in long-term ecological damage (10 years) in a Massachusetts marine system (U.S. Department of the Interior, 1983). Thus, chemical composition is of prime importance in determining the severity of impacts. In general, lighter oils leave less residue that can reach sediments or shorelines, assuming that the oil has had time to evaporate and dilute.

(d) Impacts to Water Quality. Addition of some pollutants to Sampit River and Winyah Bay waters would occur as a result of process and blowdown water discharge from the proposed Carolina Refining and Distributing Company's refinery. The extent of any water quality degradation would vary, however, depending upon the constituent under consideration, location of outfall, and other chemical, biological and hydrologic characteristics at the time of discharge. The estimated concentrations or amounts of the constituents within the refinery discharge, the applicable water quality standards or guidelines, and general chemical fate considerations have been previously summarized in Table VII.B-10. The following discussion will consider the movement and dilution of the expected constituents of the refinery effluent following mixing within the Sampit River.

As mentioned previously in Section VI.C.3.d, a numerical model exists that can be adapted to flow conditions of the Sampit River and can aid in assessing the water quality impact of wastewater discharged into the river. This model, called RECEIV II, is utilized by the South Carolina Department of Health and Environmental Control (DHEC) to analyze the impact of various industrial discharges to the Sampit River, particularly the impact on dissolved oxygen levels. Through cooperation with DHEC, RECEIV II model simulations were conducted to assess the dilution and movement of pollutants in the Sampit River. Models were not available, however, for analysis of pollutant movement throughout Winyah Bay.

The RECEIV II model is a modified version of the original receiving water module of the Storm Water Management Model (SWMM). The SWMM was developed through combined efforts of Metcalf and Eddy, Inc., the University of Florida, and Water Resources Engineers, Inc. in 1971 to route storm-generated hydrographs and pollutographs from watershed to receiving waters (Johnson and Duke, 1976).

The RECEIV II model is a one-dimensional model with two main computational components, one for hydrodynamic characteristics and one for water quality. Various hydraulic, hydrologic and ambient water quality parameters are provided as input to the model for the water body being simulated. For computational purposes, the water body is sectioned into channels that connect at junctions. Figure VII.B-1 shows the node or channel segmentation used for modeling of the Sampit River.

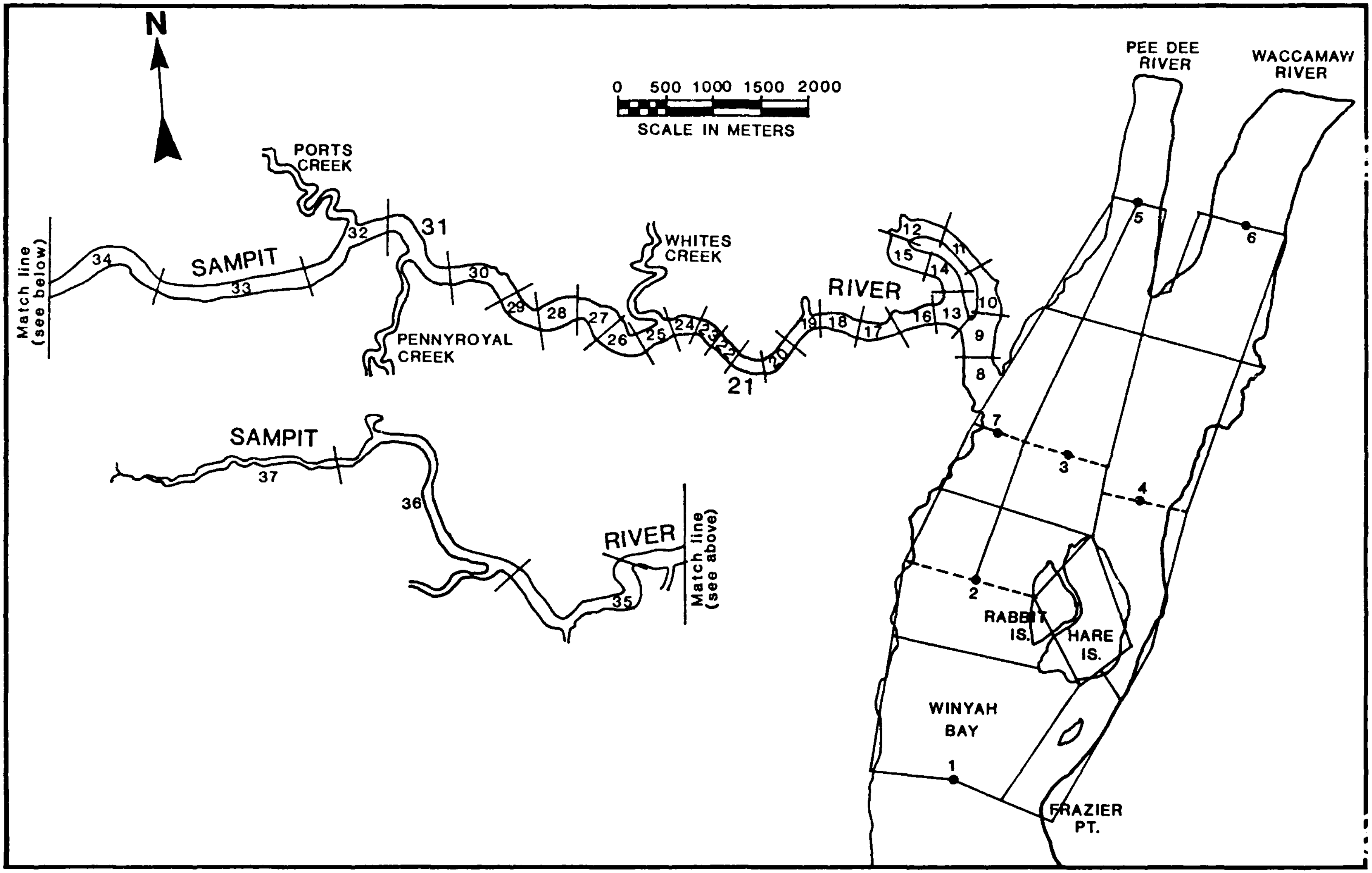

Figure VII.B-1. Sampit River RECEIV Model node segmentation (SCDHEC, 1984b)

Two simulations were run for the Sampit River, one with discharge of refinery effluent into Node 21 and another with discharge into Node 31. These two points were selected as representing potential discharges directly to the Sampit River from the Myrtle Grove alternative location and the proposed Harmony Plantation location, respectively. Refinery effluent volume flow rate was set at 4.16 MLD (1.1 MGD), with a conservative (dissolved, non-degradable) pollutant concentration of 1.0 mg/l and an estimated oxygen demand of 524,353 gms/day (1,156 lbs/day; combined demand from ammonia and other organics). Background levels of the conservative pollutant were set at zero for the Pee Dee and Waccamaw Rivers and the ocean boundary. Dissolved oxygen levels were set at 4.5 mg/l for the Sampit River, 4.2 mg/l for both the Pee Dee and Waccamaw Rivers and 6.9 mg/l for the ocean boundary. Pee Dee, Waccamaw and Sampit River flows were set at 6,400 cfs, 6,700 cfs and 40 cfs, respectively. These flows were chosen as representing average low summer flows. The Waccamaw flow as input to the model represents combined Waccamaw flow and a portion of the Pee Dee River flow that connects to the Waccamaw River through Bull Creek. Dilution of conservative pollutants from the refinery would not be expected to vary greatly in the Sampit River for varying freshwater inflows to Winyah Bay, however, these inflows would probably affect dilution in Winyah Bay.

The first simulation was for a discharge into Node 21 of 1.0 mg/l of a conservative substance in a volume flow rate of 1.1 MGD. Simulation was run for a total of twenty-one days, which represented the point at which equilibrium appeared to be reached. Results, shown in Table VII.B-11, indicate that the component was greatly diluted in the outfall node to a 0.0015 mg/l daily average concentration, and to even lower concentrations at the river mouth, Node 8, and Winyah Bay, Node 1. The assumptions used for the RECEIV model would be less appropriate for use of this model for Winyah Bay, even the upper portions. Therefore, the actual concentrations at Node 1 may vary from those indicted by this model. Of particular interest is that the maximum daily average concentration occurred upstream of the discharge point, in Node 30, indicating the movement of pollutants up the river from the discharge point. This can probably be attributed to tidal excursion and concentration buildup at that point due to flushing characteristics. Based upon the modeling results, the impact of the refinery waste BOD was determined to be insignificant when compared to other discharges, generally decreasing dissolved oxygen less than one-tenth of a milligram per liter.

The second simulation was for a discharge into Node 31 of 1.0 mg/l of a conservative substance under the same conditions as before. Results of this simulation, shown in Table VII.B-11, indicate that the maximum daily average is reached in the discharge node. Results also show that the concentration at the mouth of the river, Node 8, is somewhat less for this outfall location than for an outfall located farther downstream. Dissolved oxygen levels in the Sampit River were decreased to a greater extent by discharge to this outfall location than for discharge farther downstream, but reduction in dissolved oxygen due to the refinery wastewater was still 0.1 mg/l or less.

Based upon the results of the two simulations, it can be anticipated that the overall wastewater pollutant concentration will be considerably diluted by discharge into the Sampit River, regardless of outfall location. However, upstream outfall locations may result in slightly lower concentrations of pollutants in Winyah Bay. Additionally, hydrodynamic characteristics of the Sampit River are such that pollutants can move upstream and accumulate to some extent when discharged in downstream areas.

TABLE VII.B-11

RESULTANT NODAL CONCENTRATIONS BASED ON RECEIV MODEL
SIMULATION OF 1.0 mg/l CONSERVATIVE POLLUTANT

Simulation 1. Outfall in Node 21

Node number	Daily avg. conc. (mg/l)*	Daily max. conc. (mg/l)**	Percent dilution
30	0.0018	0.0021	99.79
21	0.0015	0.0026	99.74
8	0.00051	0.0012	99.88

Simulation 2. Outfall in Node 31

Node number	Daily avg. conc. (mg/l)*	Daily max. conc. (mg/l)**	Percent dilution
31	0.0040	0.0043	99.57
30	0.0036	0.0041	99.59
21	0.0018	0.0037	99.63
8	0.00040	0.0011	99.89

*Daily average after equilibrium reached (21 days). This number represents the dilution factor to arrive at daily average concentrations.

**Daily maximum after equilibrium. This number represents the dilution factor for the worst case condition.

SOURCE: DHEC , 1984b.

A number of assumptions germane to the RECEIV model itself and to these simulations should be considered in evaluating the results. As a one-dim nsional model, the RECEIV model assumes complete mixing vertically and horizontally across the river. Under conditions of high freshwater inflow to Winyah Bay, stratification in the Sampit River may occur. In this situation the RECEIV model would not be ideal for modeling of pollutant movement, and higher concentrations of pollutants may appear in channelized areas. Additionally, some concentration gradients may exist in the immediate vicinity of the discharge outfall as immediate mixing may not occur in the discharge node. This could create localized areas of higher pollutant concentration. In general, however, the assumption of complete mixing is acceptable for the majority of the Sampit River volume for most of the time.

The use of the RECEIV model as set up by the South Carolina Department of Health and Environmental Control includes carrying the simulation into upper Winyah Bay. The application of a one-dimensional model to a partially mixed estuary, such as Winyah Bay, exceeds the model's capabilities and the results of simulation for nodes one through seven are deemed unreliable. However, it can be assumed that concentrations at any point in the upper bay should be less than for Node 8 in the simulations, which is the mouth of the Sampit River.

The model used for these simulations was set up for analysis of oxygen demand imposed by discharges from the International Paper Company. As such, it was programmed for the plant's effluent BOD and included the rate constants required for this specific analysis. An additional capability to handle ammonia degradation had been incorporated as well. A model was not available specifically to handle all the characteristics of the proposed refinery wastewaters as they were discharged to the Sampit River. However the ability existed to model the discharge of a conservative (dissolved, non-degradable) substance as it was introduced into the river strictly by applying the hydraulic dilution and dispersion characteristics of the model.

Reviewing the fate characterization presented in Table VII.B-10 of the expected components of the proposed refinery's wastewater, it can be seen that most of the components will either volatilize to some extent, adsorb onto suspended particles and settle out, or partially react in some other manner in the receiving stream. This would mean that many of the constituents may build up in the sediments near the outfall. The fact that most of the constituents of the refinery effluent are not conservative makes modeling of their ultimate dispersal by use of the RECEIV model unreliable to the extent such substances deviate from the "conservative" criterion. Multiplication of expected refinery effluent component concentrations by the dilution factors shown in Table VII.B-11 would be an acceptable method to determine equilibrium concentrations in the various nodes only if the component was basically conservative.

In order to evaluate the distribution of wastewater pollutant constituents for the more non-conservative type components expected to be discharged, another approach was needed. An application of numerical values to the concentration of various pollutants in the waste stream and subsequently in the receiving stream may cause erroneous interpretations to be made, particularly since these concentrations may have been determined from estimated data or by accepting a large amount of assumptions. Therefore evaluation of the distribution of pollutants from the proposed refinery discharge should be qualitative, based upon anticipated effluent concentrations, general fate characterization of such components in the receiving

stream, and hydraulic flushing properties shown by RECEIV model simulations. Table VII.B-12 provides a summary of the expected constituents of the refinery wastewater, their anticipated effluent concentration, and a subjective evaluation of their expected retention in the water column.

e. Mitigative Measures for Controlling Impacts of Refinery Wastewaters. A number of possible industry practices for maximizing the treatment efficiency at a refinery wastewater treatment facility are presented in this section. Both refinery process and sanitary wastewaters can be managed untilizing the measures presented.

Effective monitoring of the discharged effluent with proper sampling, laboratory, and quality control would be important to assessing the effectiveness of mitigative measures. The original draft discharge permit, discussed in Section VI.C.2.b, included monitoring within the Sampit River and wastewater biomonitoring in addition to monitoring of important constituents. Monitoring frequency may require revision if refinery operations would be variable enough to warrant more frequent monitoring.

Certain wastewater treatment and disposal design considerations can affect effluent quality and impacts in waters receiving the effluent. The wastewater treatment processes can be designed with minimizing impacts on water quality in mind. For example, storage basins can be larger than proposed by the applicant if warranted in consideration of environmental impacts. Detention times for wastewater within API separation and treatment by aeration and flotation can be longer than minimum requirements, and filter surface area can be larger. The pipeline through which wastewater is proposed to be released to Turkey Creek or the Sampit River can include a multi-port diffuser to enhance mixing of the wastewater with receiving waters. As another example, the location where the wastewater is released to the recieving water, presumably within either Turkey Creek or the Sampit River, can be selected to enhance wastewater dilution.

TABLE VII.B-12

PROCESS WATER COMPONENTS: SUBJECTIVE EVALUATION OF RETENTION IN THE WATER COLUMN

Component	Estimated refinery effluent conc. (ug/l)	Existing conc. (ug/l)[1] river/bay	Expected retention in the water column	Remarks[2]
Oil/grease	28,302*	<2	medium	High propensity for adsorption and precipitation as well as some volatilization. Expect accumulation in sediments near outfall.
Phenol	241*	unk	medium**	Biodegradation expected.
Sulfide	1,206*	unk	medium	Will oxidize to sulfate and probably precipitate as calcium or magnesium sulfate.
Copper	200	<50	high	Some loss through adsorption to clay.
Mercury	60	0.4/0.5	low**	Low solubility. Expected to accumulate in sediments near outfall.
Zinc	1,100	<50/110	low	Same as mercury.
Benzene	<10	unk	low	High volatility. Expect little distribution.
Ethylbenzene	<10	unk	low	Same as benzene.
Methylene chloride	100	unk	low	Same as benzene.
1,1,2,2-Tetrachloroethane	<10	unk	low	Same as benzene
Tetra chloroethylene	<10	unk	low	Same as benzene.
Toluene	30	unk	low	Same as benzene.
1,2-Trans dichloroethylene	<10	unk	low	Same as benzene.
Trichloroethylene	<10	unk	low	Same as benzene.
2,4 Dimethy phenol	<10	unk	medium	Same as phenol.
4-Nitrophenol	<10	unk	medium	Same as phenol.
P-Chloro-m-cresol	<10	unk	medium	Same as phenol.
Anthracene	1	unk	low**	Loss through photolysis and biodegradation.
Benzo (a) pyrene	5	unk	low**	Practically insoluble. High propensity for adsorption and precipitations. Expect accumulation in sediments near outfall.
Bis (2-ethyl-hexyl) phthalate	2,000	unk	medium	Insoluble in water. Expect some adsorption and slow degradation.

TABLE VII.B-12
(continued)
PROCESS WATER COMPONENTS: SUBJECTIVE EVALUATION OF RETENTION IN THE WATER COLUMN

Component	Estimated refinery effluent conc. (ug/l)	Existing conc. (ug/l)[1] river/bay	Expected retention in the water column	Remarks
Chrysene	50	unk	low	Same as mercury.
Diethyl phthalate	30	unk	low	Insoluble and relatively short lived.
Napthalene	1	unk	low**	Same as anthracene.
Phenanthrene	1	unk	low**	Same as Benzo (a) pyrene.
Pyrene	10	unk	low**	Same as Benzo (a) pyrene.
PCB (various)	<10	unk	medium**	Some adsorption to suspended organic particulates.

unk = unknown

[1]Based on 1983 reported levels for stations MD-077 and MD-080 (DHEC, 1984a). Oil and grease levels estimated.

[2]Based on Table VII.B-10.

*Total mass discharged divided by total continuous wastewater flow.

**Since these components can bioaccumulate, expected retention in water column may not reflect levels to be found in aquatic organisms or in sediments.

Wastewater treatment facilities need to be properly operated if wastewater treatment efficiencies are to be maximized. A complete operation and maintenanc manual is needed that describes operation of each wastewater treatment process and how to troubleshoot problems. Spare parts must be easily obtainable. Operators need to be properly trained and preferably involved with continuing education.

Increasing the extent to which treated wastewaters can be reused within the proposed refinery would reduce impacts of wastewater on receiving water quality. Waters from one refinery process may be useable in a second refinery process, or recycling of water within a particular process is often possible. However reuse does not always result in smaller quantities of wastes being generated.

Dry cleaning techniques, preferably without chemicals, also can reduce wasteloads to be treated at the refinery wastewater treatment plant. Oil can be recovered for processing and eventual use as well.

To best manage solid wastes, the landfill at which the wastes would be disposed can provide a compatible liner, groundwater monitoring around the landfill, leachate detection and dikes or berms to keep runoff from upstream areas away from the landfill. Many of the listed measures also would be suitable if the solid waste were to be spread on land in a more liquid form rather than disposed of at a landfill.

From the government perspective, ensuring compliance with discharge permit requirements would be a primary objective. South Carolina DHEC can investigate monitoring procedures to satisfy itself that the measured treated effluent flows and concentrations are reliable. If measured flows and concentrations result in discharge permit violations, the refinery could be required to improve wastewater treatment, spill prevention or runoff control practices. Improved operator training, better equipment or equipment maintenance, and better use of water storage facilities are some of the practices that could be specified in order to better meet permit requirements. Monitoring at the solid waste landfill where refinery solid wastes would be disposed can be investigated and needed mitigative measures can be proposed by the governing agency in the same manner that wastewater practices can be enforced.

South Carolina DHEC also can consider evaluating the need for additional wastewater treatment at the proposed CRDC refinery. Clearly the applicant takes responsibility for abiding by the discharge permit requirements. However the governing agency may wish to discuss with the refinery wastewater engineers the basis for selecting or not selecting certain treatment processes and the basis for selecting particular sizes and special equipment for each process.

Additional wastewater treatment measures that could be used to produce an effluent with lower concentrations of pollutants would include activated sludge biological treatment, which could reduce BOD, COD and ammonia levels; rotating biological contractors, which could also reduce these same constituents, particularly ammonia; and tertiary filtering with activated carbon adsorption, which would reduce the levels of most all of the organic compounds and suspended solids (Manning and Snider, 1983).

(2) Sanitary Wastewaters. The most recent information, as received from Ford, Bacon and Davis, Inc., indicates that sanitary wastewaters from the proposed CRDC refinery would be discharged to a publicly owned treatment works at a flow of 14,194 liters per day (3,750 gallons per day). The amount of sanitary wastewater generated by refinery employees can range from approximately 57 to 0114 liters (15 to 30 gallons) per person per day, depending on the types of toilets and sink faucets used. Pollutant loadings would not vary greatly with toilet and faucet types. Sanitary flows and pollutant loadings would be higher if showers are utilized by employees.

Typical pollutant loadings within untreated, municipal wastewaters (households and other non-industrial sources) are: 200 to 300 mg/l of five-day biochemical oxygen demand (BOD_5); 200 to 250 mg/l of total suspended solids; 400 to 600 mg/l of colloidal and dissolved solids; 20 to 25 mg/l of total nitrogen, approximately 10 mg/l of total phosphorus; and concentrations of 5 mg/l or lower of microorganisms, metals, and organic compounds. Wastewaters from only toilets and faucets would probably have lower nutrient concentrations than household wastewaters, because the volume of wash water would not be as large. Following proper secondary treatment (usually consisting of biological treatment and settling), the average daily effluent from a municipal wastewater plant would contain the following: 30 mg/l BOD_5, 30 mg/l total suspended solids, 20 mg/l of total nitrogen, 10 mg/l of total phosphorus and much lower levels of microorganisms (as indicated by coliform bacteria), metals and organic compounds than are present in wastewater entering the treatment plant. Nitrogen and phosphorus are usually not removed from wastewater during secondary treatment. Metals and, to a lesser extent, organic compounds become primary components of the sludge disposed as solid waste. Most microorganisms are killed as a result of disinfection.

Based on available information, sanitary wastewaters from the proposed CRDC refinery will be discharged, in conjunction with wastewaters from the City of Georgetown, to Winyah Bay via Whites Creek and the lower Sampit River. Most of the effluent would be soluble upon contact with estuarine waters, depending upon pH, other chemical factors and treatment efficiency. Upon release, the wastewater would flow with wind, tidal, and freshwater current forces through Winyah Bay to the Atlantic. The volume of sanitary wastewater from the refinery would constitute less than one percent of the volume and pollutant loadings from the City of Georgetown.

Secondarily treated wastewaters can affect the water quality of an estuary in a variety of ways:

- dissolved oxygen levels can be reduced by BOD if wastewaters do not mix with large volumes of receiving waters;
- solids in treated wastewaters can inhibit the vertical penetration of light in the water column, which can result in reduced phytoplankton growth;
- phytoplankton growth may be encouraged by the addition of nutrients (nitrogen, phosphorus, metals);
- metals and organic compounds can be assimilated by estuarine organisms, including fish, which can be potentially dangerous for human consumption;
- bacteria and viruses can make shellfish unsuitable for consumption and waters unsuitable for human recreation.

Reductions in dissolved oxygen can change the entire affected estuarine habitat to one dominated by non-indigenous populations. The addition of solids can inhibit phytoplankton growth by reducing the penetration of light needed for photosynthesis. Nutrients that limit phytoplankton production may vary with season or location within Winyah Bay. Discharge of nutrients to Winyah Bay that normally limit phytoplankton growth could augment such growth, thus contributing to eutrophicating conditions. Growth of some "nuisance" phytoplankton species to bloom proportions can cause severe oxygen depletion and reductions in species diversity.

Estimates from South Carolina DHEC show that sanitary wastewater impacts would be under control, provided effluent limitations listed in the state discharge permit for the City of Georgetown WWTP would be met. This estimation of impact control is based on a judgment as to how much wasteload Whites Creek and Winyah Bay can assimilate at any location and still maintain acceptable water quality conditions. However assimilative capacity is nearly impossible to quantify effectively because of the complex hydrodynamics of the Winyah Bay system and the unpredictability of weather conditions.

Impacts of sanitary wastewater on water quality can be explained qualitatively for Georgetown but not quantitatively. Reductions in dissolved oxygen in the receiving water can take place if the wastewater is not diluted sufficiently and/or the wastewater-water mixture is not sufficiently aerated. Nutrients, metals and various organic compounds in sanitary wastewater are also added to the receiving water. One quantitative consideration is clear; the amount of sanitary wastewater added to the Sampit River and Winyah Bay from the proposed refinery would be much less than one percent of the wastewater discharged from the city of Georgetown.

Many of the mitigative measures listed for process waters also can be applied to sanitary wastewaters. Sanitary wastewater from the refinery would be routed to the City of Georgetown Wastewater Treatment Plant, which would be responsible for treatment and disposal. Proper treatment plant operation, equipment maintenance and monitoring would be important to maintaining effluent quality and, thereby, controlling the pollutant loads reaching Winyah Bay.

(3) Runoff and Small Unavoidable Handling Losses. Stormwater runoff flows and water quality vary with rainfall intensity, rainfall duration, site topography, soil characteristics, refinery operations, and elapsed time since the most recent storms. At a refinery site, topography and drainage patterns can be controlled to separate runoff that contacts oil or other refinery wastes from runoff that does not contact such wastes.

The most recent information concerning flows emitted from the proposed CRDC refinery (Table VII.B-4) estimates that 946,250 liters (250,000 gallons) per day of oil-contaminated stormwater would be generated. It has been proposed that drainage patterns would be controlled so that stormwater that does not contact oil at the refinery would be segregated and released to downstream waters without treatment. Oil-contaminated stormwater would be passed through an API Separator prior to discharge (Taggart, 1983). Large quantities of oxygen-demanding substances, suspended solids and oil and grease can be associated with oil-contaminated stormwater (Manning and Snider, 1983). Runoff from scrub hardwood areas also can include oxygen-demanding substances, solids and nutrients.

During a storm, most pollutants are washed from the ground within the first few hours. This "first flush" phenomenon also occurs at refinery sites. Studies have shown that sixty to eighty percent of organic materials were washed from the land surface at a refinery during the first hour of a rainfall (Manning and Snider, 1983). "First flush" characteristics can vary from site to site, depending primarily upon storm characteristics, topography, soil type, and the amount of wastes vulnerable to runoff. Along the southeastern United States coast, the most intense storms generally occur during July and August (Novotny and Chesters, 1981).

The API Separator proposed to treat oil-contaminated runoff is a gravity-separation process. For refinery wastewaters, the API Separator, at best, can achieve an effluent oil concentration of 50 mg/l (Manning and Snider, 1983). The amount of flow entering an API Separator during and following a storm varies over time, resulting in less than optimal conditions for gravity-separation treatment.

The impact of oxygen-demanding substances, suspended solids, oil and grease, nutrients, and bacteria and viruses in refinery process and sanitary wastewaters has been discussed previously and is summarized in Table VII.B-11. The impact of these parameters will vary with the type of oils released, aquatic species within the receiving waters, life stage of species, time of year and hydrodynamics of the receiving water. Water movement within Turkey Creek and the Sampit River is controlled primarily by tides. Detention times for waters within Turkey Creek have not been quantified by dye-release measurements. The effect of combinations of chemicals has not been thoroughly studied by researchers; the nature of these mixtures in runoff can vary greatly within and between storms.

Refined oils, often associated with small unavoidable handling losses at a refinery, are often more toxic to receiving waters than crude oils (MITRE Corp., 1981). Soluble fractions of petroleum are probably the most harmful fractions to marine organisms. The interaction of temperature and salinity variations with stress from hydrocarbon pollutants may aggravate adverse effects, particuarly in estuaries where biological productivity is relatively high (National Academy of Sciences, 1975).

Both runoff and small unavoidable handling losses have the potential for causing small-scale yet chronic problems if not controlled. Mitigative and enhancement measures discussed in the following section, if adhered to, would lessen their severity. Additionally most of the constituents of sludge processing wastes such as phenols, benzene and heavy metals are considered hazardous and require state approved storage, treatment and disposal practices.

Heavy metals would be of particular concern if released to the aquatic environment, since they could accumulate in the sediments, especially in the fine-grain sizes. Some accumulation in sediments also would occur in the case of petroleum products. Problems would be centered in the lower Sampit River and upper Winyah Bay. Proper control techniques and an adequate monitoring program would be needed to both define and manage the scope of this problem.

Mitigative measures in the forms of runoff and spill control and runoff treatment can help to control adverse impacts from runoff and spills at the refinery site and at the pier where the tankers would unload. Results from monitoring activities would help to assess the need for mitigative measures, in addition to those to be included before the refinery is put in operation.

Discharge permit requirements, which have been specified for total organic carbon and oil and grease, are more difficult to enforce for runoff than for wastewater. Runoff flows are intermittent and vary widely in magnitude. Monitoring for flow and water quality would need to be conducted almost continuously to determine if maximum concentrations are exceeded for a number of rainfall events. However monitoring is still encouraged for the specified parameters at time intervals during and after significant rainfalls. Monitoring strategies can be specified by South Carolina DHEC. A suitable monitoring station at the lowest elevation bordering the site, near the adjacent water body, could be installed as the site is developed.

Various measures for controlling runoff impact during construction also apply to post-construction periods. Measures to control the impacts of construction are discussed in Section VII.B.1.d. Maintenance of suitable soil and vegetative cover, the use of temporary sediment traps set in place prior to storms, and proper use of runoff storage and treatment facilities are all important measures for controlling adverse environmental impacts.

A number of measures are available for controlling spills at the refinery site or at the pier, where it is proposed that tankers are to unload:

- Title 33, Parts 154 through 157 of the Code of Federal Regulations must be followed (Part 154-"Large Oil Transfer Facilities", Part 155 -"Vessel Design and Operations," Part 156 - "Oil Transfer Operations," and Part 157 - "Rules for the Protection of the Marine Environment Relating to Tank Vessels Carrying Oil in Bulk");

- construction of dikes around oil storage areas and refinery units with certain specifications;

- use of vacuum trucks or other dry methods to clean up spills at the refinery or dock facilities;

- recovery of as much oil as possible for processing rather than disposal;

- periodic flushing of pipelines within the refinery with waters to be treated in combination with process waters;

- shutdown procedures to be utilized prior to the possibility of a tropical storm or hurricane;

- allowing tanker trucks taking refined products from the refinery to flush only at preferred, carefully controlled sites where wastes can be easily routed to refinery sewers. Flushing within the refinery itself also can be carefully controlled with proper procedures and timing.

In addition, the most recent information from Cathcart (1982) refers to oil-free and oil-contaminated stormwater. A closed drainage system within the oil-contaminated area leading to an API Separator, together with cooling water blowdown, is apparently being proposed.

Runoff treatment, in addition to the API Separator, is possible. Skimming within a storage sedimentation basin and dissolved air flotation can be particularly worthwhile for reducing oil and grease concentrations in runoff waters.

Costs, implementation and operation of various mitigative measures would need to be compared with the effectiveness of each measure in reducing environmental impacts. With such a comparison, certain mitigative measures can either be required by the governing agency as part of a discharge permit, or encouraged but not required. Monitoring of refinery and pier operations to guarantee effective implementation and operation of mitigative measures would be the responsibility of South Carolina DHEC. Runoff flow and water quality monitoring procedures would be agreed to jointly by the permittee and South Carolina DHEC. Monitoring procedures for runoff flow and water quality would need to be extensive enough to allow for assessment of the overall effectiveness of the permittee in meeting whatever runoff discharge permit requirements are to be established in final form.

A recent petroleum refining settlement agreement includes new limitations for stormwater runoff. This agreement is effective 1 May 1984, and proposes that permit writers be required to give stormwater allocations for contaminated runoff. Stormwater allocations are given for total suspended solids, BOD_5, oil and grease, pH, total phenols, total chromium and hexavalent chromium.

b. Oil Spills

(1) Probability of Occurrence - Summary of Existing Analyses

(a) Introduction. During the last three years, many well-qualified individuals have studied the proposed CRDC oil refinery from the stand-

point of ascertaining the likelihood of an oil spill that would impact Winyah Bay and its environs. In addition, some studies have been revised. The net result is that different and widely varying estimates have been made of the probability of an oil spill. Rather than engage in an independent analysis of oil spill risks, it is the purpose of this section to review the work that has been performed to date and assemble the pertinent data and findings from these studies in one presentation. Hopefully, this will eliminate the confusion that has surrounded the oil spill issue in the past.

A few comments on the general techniques that are employed in developing oil spill probabilities are appropriate so that it may be understood how variations can arise in estimating spill probabilities. A risk of an oil spill exists for all oil transportation operations. The historical record for Winyah Bay is excellent, with no spills resulting from vessel accidents and only a single spill of two gallons associated with oil transfer operations. This spill occurred at the Hess Oil Dock on 5 April 1976. It is therefore tempting to conclude that there is an extremely small potential for spills based upon the history of Winyah Bay. However, as Muga and Smith (1981) point out, such a conclusion is faulty because it is based upon a small data base and is of questionable statistical reliability. Therefore, each of the studies that have been conducted has been based upon far more extensive data bases of tanker accidents and spills than the data base available for Winyah Bay. The choice of the data base alone will influence the results of the analysis, leading to disparities among the results of different analyses. In the same manner, the treatment of other factors can lead to different results.

Three distinctly separate analyses have been performed for risk assessment of oil spills in Winyah Bay, assuming the CRDC refinery becomes operational. They are as follows:

- Analysis by Davis and Floyd Engineers, Inc. (1981) using the TRAM model developed by Ozkaynak, Murphy and Watson (1979) and presented in the revised environmental assessment;

- Analysis by Gundlach included in "Evaluation of CRDC Submittals for a Proposed Oil Refinery at Georgetown, South Carolina," prepared for South Carolina Coastal Council by Wilbur Smith and Associates, 1981;

- Analysis by Muga incorporated in "An Evaluation of the Environmental Assessment Document for a Proposed Refinery, Georgetown, South Carolina" prepared by Bruce J. Muga and Associates and Wilbur Smith and Associates for South Carolina Coastal Council, 1981.

Each of these analyses will be discussed separately to enable the reader to comprehend the methodology involved.

(b) Analysis by Davis and Floyd Engineers, Inc. (1981). Davis and Floyd Engineers, Inc. employed the tanker oil spill risk assessment model (TRAM) that was developed by Ozkaynak et al. (1979). In their paper, Ozkaynak et al. point out that the magnitude and severity of the oil spill risk associated with a specific project, such as the CRDC refinery, is related to environmental and geographical considerations. A study to determine oil spill probabilities is based upon such factors as fleet composition, navigational aids, and particulars of the route. Thus, it is clearly recognized that the study of oil spill risk is site specific. Tanker oil spills are caused by routine operations or accidental tanker casualties. The TRAM model quantifies the risks of casualty related spills in terms of spill probabilities and spill volumes.

The TRAM model computes spill probabilities and volumes for total vessel losses and less than total vessel losses. Probabilities are given separately for five categories of accident location (pier, harbor, entrance, coast and open sea). Factors used by the model are the probability of an accident for a particular voyage, the probability of a spill once an accident has occurred, and the probability that the vessel is a total loss, given that a spill has occurred. The above probabilities are based on worldwide data for the period 1969 to 1972. The model modifies the probabilities based on worldwide data by taking into account vessel-specific and route-specific features. The vessel-specific feature is based upon vessel characteristics such as size, age and method of construction. The authors of TRAM point out that the casualty exposure factor based upon fleet composition is perhaps the single most important factor influencing the outcome of an oil spill risk analysis. Further, spill probabilities are considered to be proportional to the number of port calls made.

The TRAM model utilizes a detailed approach to formulating spill probabilities. Results obtained from the model are dependent upon the choices made for the various data inputs used by the model.

Davis and Floyd Engineers, Inc. calculated spill probabilities for existing harbor traffic (assumed to be 40 tankers or barges per year), traffic for the proposed CRDC refinery (72 tankers per year) and the combined total traffic of 112 tankers per year. Only the combined traffic will be discussed here since it appears to be the pertinent consideration in determining oil spill risks to Winyah Bay following the construction of the CRDC refinery. It was mentioned above that TRAM distinguishes between spill locations. In applying TRAM to Winyah Bay, accidents occurring in the coastal or sea categories are not considered since they are extremely unlikely to affect Winyah Bay. The coastal category describes vessels within 92.6 km (50 naut mi) of shore and the sea category is for vessels outside the 92.6-km (50 naut mi) limit. Spills occurring at the mouth of Winyah Bay would be accounted for in the category describing vessel locations at the entrance to a harbor, bay, river or strait. For this analysis, however, it is appropriate to sum accident probabilities for pier, harbor and entrance location categories since an accident in any of these locations will affect Winyah Bay. Ozkaynak et al. (1979) define the harbor location as being "within the confines of a harbor, bay, river and so forth." The data base of worldwide accidents used by TRAM reflects this definition of the term "harbor." For this particular analysis, therefore, the term "harbor" is interpreted to mean the entirety of Winyah Bay.

The TRAM model analysis, as performed by Davis and Floyd Engineers, Inc. assigned probabilities to pier, harbor and entrance locations for total loss and less than total loss oil spills within Winyah Bay. For a total loss spill, these probabilities are 0.0011, 0.0010 and 0.0007 per year, the sum of which, 0.0028 per year, may be expressed as a total loss occurring once in 357.1 years. For a less than total loss spill, the probabilities are 0.0142, 0.0218 and 0.0157 per year, the sum of which, 0.0517 per year, may be expressed as a less than total loss occurring once in 19.3 years.

The spill sizes associated with these losses are presented by TRAM in terms of the number of barrels per year; in other words, the annual spill rate based upon the return intervals already computed. It is more meaningful to deal in terms of the actual volume associated with the spill, should it occur. For a total vessel loss, the worst case would involve the loss of the entire contents of the vessel. The vessels serving the CRDC refinery have been described as carrying a maximum cargo of 140,000 barrels.

The TRAM analysis indicates the spill size for a less than total loss as ranging from 17.4 barrels per year at the pier to 49.5 barrels per year in the harbor, i.e., Winyah Bay (a spill size of 42.0 barrels per year is indicated for the harbor entrance). The return intervals of accidents causing these spills are given as one in 70 years at the pier and one in 46 years in the harbor. Multiplication of the annual spill by the return interval, in years, yields the volumes actually associated with the spill, should it take place. Results of this multiplication yield volumes of 1,218 barrels per event at the pier and 2,277 barrels per event in the harbor (Winyah Bay).

The return frequencies and spill volumes given above are taken or derived from the output of the TRAM model by the analysis of Davis and Floyd Envineers, Inc. The complete set of input data is not known, although values used for many of the parameters were from those provided in the paper by Ozkaynak et al. (1979) according to Davis and Floyd Engineers, Inc. (1981).

(c) Analysis by Erich Gundlach (1981; as cited in Bruce J. Muga and Associates and Wilbur Smith and Associates, 1981). Gundlach utilized the approach of Beyer and Painter (1977) to estimate the average amount of oil spilled from tanker accidents occurring within 80 km (50 stat mi) of shore based on the volume of oil transported and the number of port calls. Both of these parameters have been used in previous studies of exposure to environmental risk. Goldberg et al. (1981) have pointed out that measures to accurately reflect a tanker's exposure to risk have yet to be developed, primarily because analysts do not know the contribution to accident frequency from each of the many environmental hazards.

Although an accident within 80 km (50 mi) of Winyah Bay could impact the environment of the Bay, it is reasonable to conclude that such an analysis is conservative since it is unlikely that oil released at seaward limits of this 80 km range would drift into Winyah Bay, which is approximately 1.6 km (one mi) wide at its mouth.

The data base employed by Gundlach was worldwide tanker casualties occurring from 1969 to 1973, essentially the same as that used in the TRAM analysis described above. Gundlach considered only the oil transport operations associated with the CRDC refinery as opposed to total oil transport operations in Winyah Bay.

Analysis of the data base in terms of the volume of oil transported indicates that 87 barrels of oil are spilled for every million barrels transported. Based on the CRDC refinery production figures, Gundlach estimated a spill volume of 317.6 barrels/year. The second approach was based on 72 port calls to the CRDC refinery, an average spill rate of 0.92 nearshore spills per 1000 port calls and an average spill size of 7,124 barrels per spill. These inputs resulted in an estimated spill magnitude of 471 barrels per year. Although Gundlach did not estimate return intervals between spills, dividing his average spill size by the volume of oil spilled per year gives return intervals of 22.4 and 15.1 years, respectively, for the two analyses.

(d) Analysis by Bruce J. Muga and Assoicates and Wilbur Smith and Associates (1981). Muga and Smith performed an oil spill probability analysis that considered spills that might result from accidents between the pier and the mouth of Winyah Bay. Because it is based on historical data, the analysis is inherently conservative because these data do not reflect the influence of technological improvements on ship design, terminal design or navigational aids. Also, the influence of more rigid regulation, training and safety standards are not reflected.

The accident data base used for tanker ships was assembled by Engineering Computer Optecnomics and was derived from Lloyds Weekly Casualty Reports, International Maritime Consultative Organization (IMCO) Casualty data, USGS files and various operating company sources. These data were compiled into a single, worldwide tanker-casualty file covering the period 1969 to 1978. Muga and Smith extracted and used incidents involving vessels between 20,000 DWT (dead weight tonnage) and 50,000 DWT that occurred within 80 km (50 mi) of the coast.

Muga and Smith chose to deal with two classes of spills, which were categorized as being catastrophic and non-catastrophic. The division between these categories was defined in terms of the number of tanks in the compartmentalized tanker ship involved in the spill. Catastrophic spills were defined as those involving more than two wing tanks which, for the size of tankers that would serve the CRDC refinery, would represent a volume of approximately 7,600 barrels. A loose comparison may be made between the catastrophic and non-catastrophic categories adopted by Muga and Smith and the total spill and less than total spill categories used by TRAM.

Muga and Smith reasoned that the frequency of spill events has statistical regularity, whereas the magnitude of the oil spill does not. Spill size ranges from a few gallons to tens of millions of gallons covering several orders of magnitude. Further, whereas most spills are at the lower end of the range of volumes, the bulk of all oil spilled results from a small number of accidents. The data base indicated that less than 10 percent of pollution-causing incidents accounted for more than 70 percent of the total volume of oil spilled. The data can easily be skewed by one large spill. To prevent this, and also to facilitate the statistical analysis, the two classes of catastrophic and non-catastrophic spills were considered separately. The resulting analysis indicated a return interval of 27 years for a non-catastrophic spill and 284 years for a catastrophic spill involving vessels between 20,000 DWT and 50,000 DWT that may occur within 80 km (50 mi) of the coast.

Muga and Smith pointed out the problems in developing estimates of spill volumes associated with the non-catastrophic and catastrophic events. There is a lack of information on characteristics of vessels serving the proposed refinery, which is understandable since the operation is likely to consist of chartered vessels serving the spot-market trade. It is unlikely that the marine operation would consist of dedicated tankers. To overcome this, Muga and Smith assumed typical characteristics of a 20,000 DWT tanker having a cargo capacity of 150,000 barrels (according to Schiro [1984] this size tanker has a capacity of approximately 140,000 barrels). By definition, the upper limit of spill volume would be 7,600 barrels for a noncatastrophic event involving a 20,000 DWT tanker. However, considering specifics of Winyah Bay (i.e., soft bottom and low traffic density), Muga and Smith reasoned that a conservative upper limit for a non-catastrophic spill would be 1,000 barrels. The data base for tankers ranging from 20,000 to 50,000 DWT shows an average spill volume of 3,700 barrels for accidents of all categories, but only 1,900 barrels for a ramming of a loaded tanker with a fixed object.

In addition to accidents caused by tanker ships, accidents involving tank barges were also considered. The data base consisted of U.S. Coast Guard Commercial Vessel Casualty (CVC) files for 1972 to 1977 and the U.S. Army Corps of Engineers Waterborne Commerce Statistics for the same period.

Return intervals for total Winyah Bay traffic were estimated to be 69 years for a non-catastrophic spill and 2,005 years for a catastrophic spill. It is seen that there is less likelihood of a spill from tank barges than with tanker ships. In reality, tanker traffic in Winyah Bay will consist of a mixture of tank barges and

tank ships. The analysis of tank barge traffic by Muga and Smith with lower estimated accident frequencies, serves to show that analyses considering only tanker ships provide a measure of conservatism.

(e) Comparison of Analyses. The preceding pages have summarized the considerable efforts of previous investigations in determining the statistical likelihood of oil spills in Winyah Bay due to oil tanker traffic serving the CRDC refinery together with existing vessel transport operations of petroleum products. The individual discussions have been directed toward commonalities in the analyses in an effort to resolve concerns regarding the disparity between results obtained by the separate investigators.

Table VII.B-13 compares results from the separate investigations. Regarding the return intervals given in the table, there is good agreement between the TRAM analysis and the Muga and Smith analysis. It should be kept in mind that the categories in the table headings (non-catastrophic and catastrophic) are those used by Muga and Smith but these categories have a loose parallel in the less than total and total categories adopted by TRAM. All findings result from worldwide tanker data bases. The data base used for the TRAM analysis is not as recent or lengthy as that used by Muga and Smith. Since marine safety standards have improved with the passage of time, it could be argued that the TRAM analysis is more conservative by today's standards. Goldberg et al. (1981) examined data from the period 1969 to 1978 for accidents occurring worldwide and reported a two-thirds decrease in the number of pollution-causing incidents during this interval. The particular circumstances of Winyah Bay further this conservatism in a number of ways. Accidents from all categories are included in the above figures. The bulk of accidents resulting in oil pollution are due to collisions and groundings. Because of the narrow channel through Winyah Bay to the pier, two ships specifically serving the Georgetown Harbor are never allowed in Winyah Bay at the same time (Doyle, personal communication, 1983), thereby diminishing the overall likelihood of an oil spill. It should be noted, however, that oil barges traversing the Intracoastal Waterway are not bound by this restriction. The channel through Winyah Bay has a soft, muddy bottom, which decreases the chances that a grounding will cause damage to the hull with a subsequent release of oil. In fact, Muga and Smith point out that groundings of vessels in Winyah Bay have occurred, but none have led to oil spills. Although these mitigating factors concerning Winyah Bay can be described qualitatively, there are insufficient data available on Winyah Bay traffic to permit a statistical analysis.

Whereas the analyses of the likelihood of pollution-causing incidents can be conducted with some confidence from worldwide data, estimation of associated spill volumes is based on more tenuous reasoning, as detailed by Muga and Smith. Spill volumes span several orders of magnitude, with the majority of spills at the lower end of the range and a small number of large oil spills constituting the bulk of all oil spilled. Lack of an accepted procedure for estimating spill volumes may account for the wider range of spill volumes provided by the individual analyses. Gundlach's analyses are difficult to compare with the TRAM and the Muga and Smith analyses because they were based upon tanker accidents occurring within 80 km (50 mi) off shore and did not differentiate between small volume and large volume spills. Muga and Smith differentiated spill volumes into two classes with a division at 7,600 barrels; this volume coincides with the likely capacity of two tanks on a ship serving the CRDC facility. TRAM simply differentiates between total vessel loss and less than total vessel loss spills. The only statistic that can be stated with any confidence is the maximum spill volume of 140,000 barrels, in the unlikely event that a total cargo loss should occur.

TABLE VII.B-13

COMPARISON OF RESULTS OF STATISTICAL OIL SPILL ANALYSES

Analysis	Return interval (years)		Spill volume	
Gundlach[1]	22.4		317.6 barrels/year 7,124 barrels/event	
Gundlach[2]	15.1		471 barrels/year 7,124 barrels/event	
	Non-catastrophic	Catastrophic	Non-catastrophic	Catastrophic
TRAM	19.3	357.1	17.4-49.5 barrels/year 1,218-2,277 barrels/event	405.8 barrels/year 140,000 barrels/event
Muga	27	284	37.0 barrels/year 1,000 barrels/event	26.8-493.0 barrels/year 7,600-140,000 barrels/event

[1] Analysis based on volume of oil transported.

[2] Analysis based on number of port calls.

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In conclusion, it appears that both the TRAM and Muga and Smith analyses provide detailed approaches to studying oil spill risks. Given that accurate measures of risk are not currently available (Goldberg et al., 1981), the fact that these two independent analyses produce estimates that are so close indicates that they mutually support each other.

(2) Hypothetical Oil Spill Scenarios

(a) Introduction. This section describes the estimated physical extent of hypothetical crude oil spills impacting Winyah Bay and the immediate vicinity. Several scenarios are presented in which factors such as the location of the spill, the magnitude of the spill and wind conditions are varied to illustrate the spectrum of possible oil spills that could occur as a result of operations at the proposed CRDC refinery.

A worst case analysis for a spectrum of potential oil spills has been conducted because 1) oil spills are reasonably forseeable events associated with the permitting of the proposed refinery, 2) significant adverse impacts are possible if an oil spill occurs, and 3) scientific uncertainties and gaps in available information exist that affect virtually all aspects of oil spills including their probability of occurrence, magnitude, environmental interactions and environmental impacts. This analysis is in accordance with the Council on Environmental Quality's (CEQ) regulations for implementing the procedural provisions of the National Environmental Policy Act (40 CFR Part 1502.22). An additional guidance memorandum that clarifies the application of the worst case analysis was published by CEQ on 23 March 1981 (46 FR 18026).

(b) Overview of Oil Spill Scenarios. A total of 17 hypothetical oil spills are considered in the worst case analysis. The circumstances of the 17 spills have been chosen to span the range of such variables as possible spill volumes, likely spill locations, and wind direction that can significantly affect the environmental consequences of the spill. In many cases, the scenarios have been chosen because they either possess a relatively high probability of occurrence or they pose a significant environmental threat to Winyah Bay.

In keeping with the spirit of a worst case analysis, conditions have not been chosen randomly but such that the consequences of the spill will be most pronounced. Some of the spill circumstances are constructed around possible spill scenarios postulated by other parties familiar with Winyah Bay and the CRDC project. The geographical locations chosen for the spill scenarios (Figure VII.B-2) span the length of Winyah Bay, from the Sampit River to the bay entrance. Circumstances and conditions considered for each scenario are summarized in Table VII.B-14. The physical effects of each spill scenario, including the movement of the oil slick, the areal extent of spreading and an indication of the segments of the Winyah Bay shoreline receiving fouling from the oil, are discussed separately in Section VII.B.2.b.(2)(c).

Spreading and movement of an oil slick is a complex process governed by several variables. Different crude oils and refined products possess different physical characteristics such as specific gravity, viscosity, and volatility. In order to adequately describe the fate of a spill all these factors should be considered. The spreading process itself undergoes a series of phases. In the initial phase, the effect of gravitational force predominates. The spreading motion is caused by the density difference between the oil and water. Fay (1969) developed the following equation for the determination of the spill diameter, D, as a function of time, t:

$$D = 2.28 \left[g \frac{(\rho w-\rho)}{\rho} V t^2\right]^{0.25}$$

where g = acceleration due to gravity
ρw = density of water
ρ = density of oil
V = volume of oil

Subsequent phases of spreading occur after several hours or days in these later phases; other parameters such as kinematic viscosity become significant and a dynamic equilibrium is established between gravitational and viscous forces. An analysis that takes such considerations into account is feasible for quiescent conditions but, in reality, the passage of time allows other factors such as fluctuating tidal currents, wind forces and bay geometry to introduce a degree of complexity into the analysis that challenges the state of the art in oil spill modeling. Recognizing the significance of these factors, the oil spill scenarios are limited in extent to the initial period of the spill during which constant physical conditions may be assumed. Therefore discussions of slick movement are limited to a complete tidal cycle at best. Tidal reversal serves to increase dispersion of the oil. In addition to fluctuating tidal forces, wind conditions are likely to vary diurnally. May (1982) felt that wind effects may be the most critical factor influencing the path of an oil spill in Winyah Bay. For these reasons, a quantitative description of slick movement over an extended time period is beyond the scope of the present study.

The effect of tidal reversal is to halt the forward motion of the oil slick and cause it to somewhat retrace its path toward the original spill location. However spreading of the slick is an ongoing process governed by the principles described above. Within the relatively narrow confines of Winyah Bay, spreading of all but the smallest volume spills will cause oil to span the breadth of Winyah Bay given sufficient time and tidal cycles.

It is important to consider here that the scenarios presented attempt to show estimated movement of a surface oil slick as it is affected by winds and current. The actual area of the rivers or bay that may receive some impact from any particular oil spill may be considerably greater than depicted with these scenarios. Processes such as emulsification could cause the volume of oil/water mixture to be greater than the slick itself would be and hence greater areas could be impacted. Likewise, adsorption of oil onto suspended particles may result in oil being transported in directions different from those modeled in the scenarios. These latter considerations, however, cannot be quantified at present.

(c) Oil Spill Trajectory Model. Many models have been formulated to describe and predict the movement of the slick resulting from an oil spill. Prediction of oil slick movement is complicated by the large number of physical processes involved and a lack of data on many of the environmental conditions that affect the transport of oil slicks. As a minimum, tidal current data, river discharge rates, and meteorological conditions must be considered in order to produce a model that will accurately describe the oil slick shape and trajectory. Although no such model meeting all criteria is available for Winyah Bay, it is fortunate that an oil spill trajectory model that takes into account these latter conditions has been developed for Winyah Bay (May, 1982).

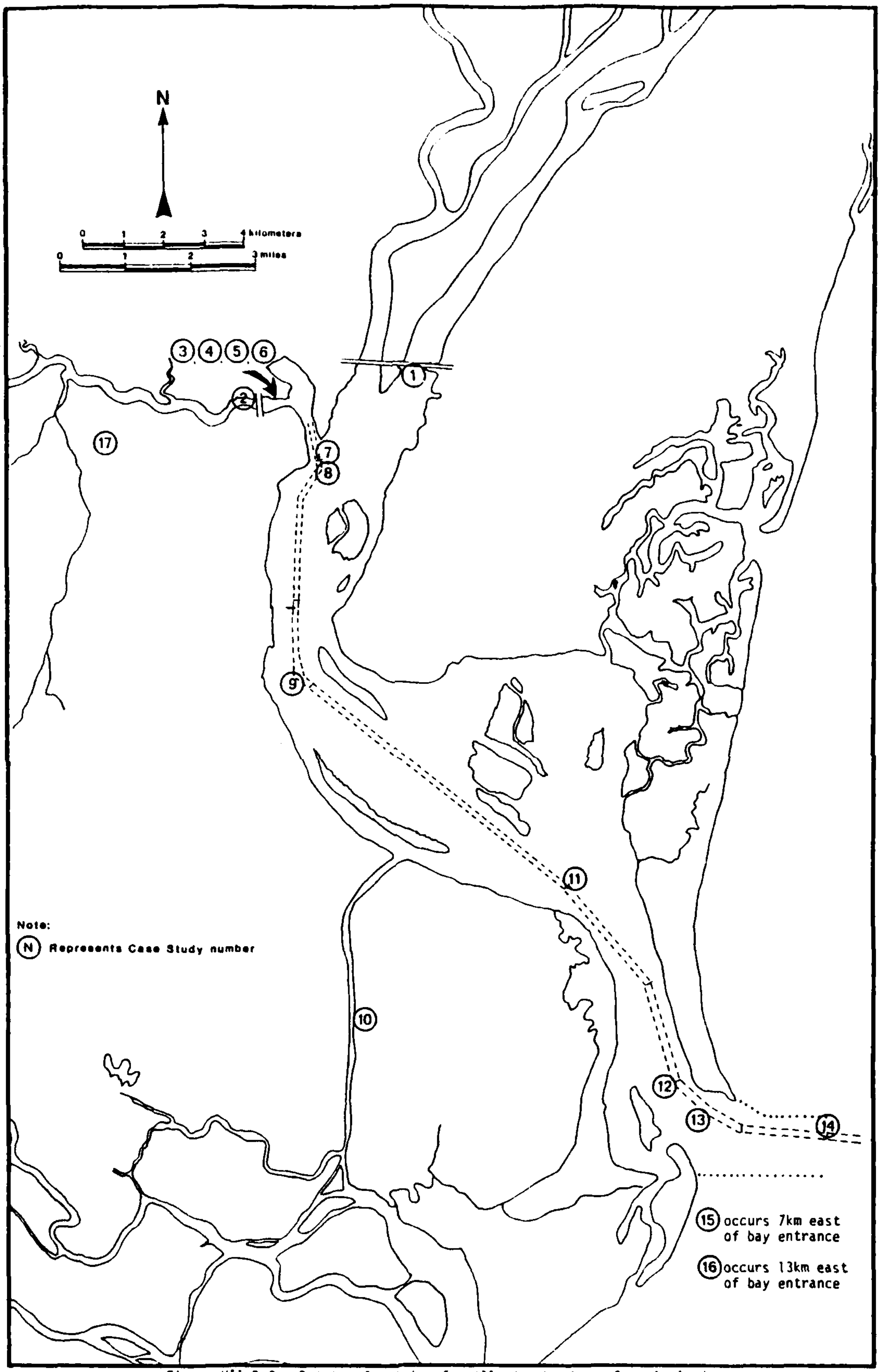

Figure VII.B-2. Points of origin of spills in the Worst Case Analysis.

TABLE VII.B-14

HYPOTHETICAL OIL SPILL SCENARIOS
WINYAH BAY AND ENVIRONS

Spill Scenario	Spill Type and Volume (barrels)	Spill location	Month of year	River discharge m^3/s^1 (cfs)	Tidal stage	Wind conditions: Bearing from north	Wind conditions: Velocity knots (mph)
Case 1	667 refined	Intracoastal waterway at the Harrell Siau Bridge over the Waccamaw River	Aug	153 (5,395)	slack low tide	215°	26(30)
Case 2	112 crude 112 refined	Sampit River at proposed pipeline crossing	Mar	874 (30,874)	slack high tide	10°	9(10)
Case 3	9.5 crude	Sampit River at Pier 31	May	455 (16,083)	slack high tide	200°	9(10)
Case 4	6.5 refined	Sampit River at Pier 31	Jan	766 (27,040)	mid ebb tide	270°	9(10)
Case 5	1,218 crude	Sampit River at Pier 31	Mar	874 (30,874)	slack low tide	90°	9(10)
Case 6	42,000 crude	Sampit River at Pier 31	Jul	372 (13,133)	mid ebb tide	300°	9(10)
Case 7	2,277 crude	Bend in channel near Sampit point	Oct	274 (9,686)	slack high tide	45°	9(10)
Case 8	17,000 refined	Bend in channel near Sampit Point	Oct	85 (3,000)	slack low tide	205°	17(20)

TABLE VII.B-14
(continued)
HYPOTHETICAL OIL SPILL SCENARIOS
WINYAH BAY AND ENVIRONS

Spill Scenario	Spill Type and Volume (barrels)	Spill location	Month of year	River discharge m^3/s[1] (cfs)	Tidal stage	Wind conditions: Bearing from north	Wind conditions: Velocity knots (mph)
Case 9	140,000 crude 17,000 refined	In channel at Frazier Point Bend	Jun	113 (4,000)	slack low tide	200°	41(47)
Case 10	1,700 refined	Intracoastal waterway midway between Minim Creek and the Western channel	Feb	854 (30,160)	slack high tide	N.A.	0(0)
Case 11	14,000 crude	In channel near Mosquito Creek	May	455 (16,083)	mid flood tide	060	17(20)
Case 12	140,000 crude	In channel 0.7 km (0.5 mi) south of Georgetown Lighthouse	Apr	427 (15,066)	slack low tide	135°	5(6)
Case 13	2,690 crude	Winyah Bay entrance, 0.4 km (0.3 mi) south of North Island	May	455 (16,083)	slack low tide	190°	9(10)
Case 14	14,000 crude	Winyah Bay entrance at North Island Jetty	Dec	991 (35,000)	mid flood tide	170°	17(20)
Case 15	140,000 crude	7 km (4.5 mi) east of Winyah Bay entrance	Sep	Not applicable	slack low tide	55°	26(30)
Case 16	140,000 crude	13 km (8 mi) east of Winyah Bay entrance	Apr	Not applicable	slack low tide	142°	26(30)
Case 17	60,000 refined	Tank farm, Harmony Plantation site	Jul	372 (13,133)	slack high tide	300°	9(10)

[1] m^3/s = cubic meters per second.
cfs = cubic feet per second.

The Winyah Bay Oil Spill Trajectory Model is based on a vector addition algorithm that includes tidal currents, river currents and wind shear stress on the water surface. It simulates the lateral displacement of a floating oil spill as it is affected by these three factors. In its present formulation, any portion of the spilled oil that is dense enough to sink is ignored. As the CRDC refinery is expected to process Venezuelan Bachaquero crude which has about 70 percent asphaltene content, a significant portion could be expected to sink. Since the model assumes that the entire spill floats at the surface, the areal extent of the spill is likely to be overestimated for the period of time discussed. However the limitation of the model to only one tidal cycle and the lack of consideration of volume increases due to emulsification will underestimate the ultimate areal extent of the spill as discussed above in the preceding section.

Input to the model consists of:

- tidal current vector matrices developed specifically for Winyah Bay by the Streamline Analysis of Currents model (Galt, personal communication, 1982);

- river current vector matrices (Galt, personal communication, 1982);

- date, time, and size of spill;

- local tide, river discharge, and wind characteristics at spill time.

The computer model tracks the centroid of the spill and computes spill diameter assuming it maintains a circular shape. This asumption is reasonable for the period immediately following the spill but, as the spill continues to spread, the circular shape will be disrupted due to the influence of shore geometry on bay currents. Hence, whereas the behavior of the slick immediately following the spill can be stated with some conviction, with increasing elapsed time following the spill there is less certainty as to the disposition of the oil.

Eventually the combination of the tide, river, and wind stresses will cause the slick centroid to make landfall. The model halts the simulation and allows the operator to use judgement as to the extent of spill grounding. If the spill has been driven directly toward shore, the bulk of the oil is likely to make landfall. Conversely, if the slick trajectory prior to landfall is tangential to the shore, a significant portion of the oil will remain afloat and will continue to drift, fouling a larger length of shoreline. In this case, the model operator can continue the simulation until it is reasonable to assume that the bulk of the spill has been grounded on the shoreline of the Bay.

The Winyah Bay Oil Spill Trajectory Model was used to provide the basis for the descriptions of hypothetical spill scenarios presented below.

Rough estimates of return intervals for these spills are also provided, where possible, by comparison with the probability of occurrence analyses treated above in Section VII.B.2.b.(1). It should be noted, however, that, in most cases, the probability estimate assigned is based only upon volume of spill occurring somewhere within the Winyah Bay area from all causes. When the specific conditions of each spill scenario are considered, the estimated return intervals would increase significantly. Therefore, since there is no method to predict the longer return intervals that would be associated with such specific conditions, the return intervals given must be considered as worst-case estimates.

(i) Case 1. This spill occurs due to a tanker barge ramming the pilings of the Harrell Siau Bridge. The barge is loaded with refined product from the CRDC refinery and is northbound in the Intracoastal Waterway. Two forward tanks of 1,000 barrel capacity rupture above the waterline, spilling one-third of their contents (i.e., 667 barrels). Physical conditions for this analysis have been chosen to determine the maximum extent to which a spill is likely to move up the Waccamaw River. Accordingly, the analysis was modeled with a low river discharge of 153 m^3/sec (5,402 cfs) and a strong wind from the southwest. Winds from other directions would cause the spill to ground on the banks of the river. It was found that a spill occuring at slack low tide would cause the slick to move 10.8 km (6.7 mi) above the Harrell Siau Bridge affecting the area shown in Figure VII.B-3 after seven hours. The ebbing tide in conjunction with river currents would serve to halt movement inland and cause the slick to drain back seaward into Winyah Bay. Although not specifically depicted in Figure VII.B-3, this refined product spill could then impact portions of Winyah Bay and could also be carried into the Sampit River. The probability of this volume of spill occurring somewhere in the Winyah Bay area from all causes, in terms of a return interval, can be estimated from the Muga (South Carolina Coastal Council, 1981) and TRAM (Davis and Floyd Engineers, Inc., 1981) analyses to be less than 27 years.

(ii) Case 2. This analyzes the effects of a rupture of the submerged pipelines crossing under the Sampit River. Since final design of the pipelines is not complete, an assumption is made that quick closure valves with automatic actuation will be employed, which would limit the volume of spill to 112 barrels for each of the two pipelines. In the worst case one pipe would contain crude oil and the other would contain a refined product leaving the refinery. At slack high tide with a north wind the oil and refined product would be pushed onto the southern shore of the Sampit River. Figure VII.B-4 indicates the area affected in the hours following the pipeline rupture. Different combinations of tidal and wind effects could serve to translocate the slick in either an upstream or downstream direction. However there would be an excellent opportunity to deploy containment devices and restrict the area affected. There is no applicable datum from which the probability of occurrence could be estimated for a submerged pipeline rupture in this location.

(iii) Case 3. This event involves a spill of 9.5 barrels resulting from a handling/transfer loss during unloading of a tanker at Pier 31. An analysis for gentle southerly winds indicate that the spill centroid would remain on the north shore of the river; however, spreading would cause the slick to span the width of the river after two hours. Oil would foul the turning basin and, on the outgoing tide, small quantities of oil could enter Winyah Bay. There is an excellent possibility that deployment of containment devices would limit the extent of fouling to that shown on Figure VII. B-5. The return interval for this spill scenario can be estimated from the Muga analysis to be one year.

(iv) Case 4. This rather small spill of 6.5 barrels of refined product occurs due to handling and transfer between Pier 31 and a tanker barge. Under the influence of a moderate westerly wind and and ebb tide much of the spilled product would be flushed out of the Sampit River and enter Winyah Bay after approximately two hours. Since containment devices, at present, are not routinely deployed during handling and transfer operations, it is questionable whether the spill could be prevented from entering the bay. Assuming the spill does enter Winyah Bay, the slick would make landfall somewhere on Rabbit and Hare Islands at slack ebb tide. Approximately half of the floating spill would be grounded. The remainder of the spill could be pushed northward on the flood tide. The westerly wind would push it ashore near the Bellfield Plantation. The extent

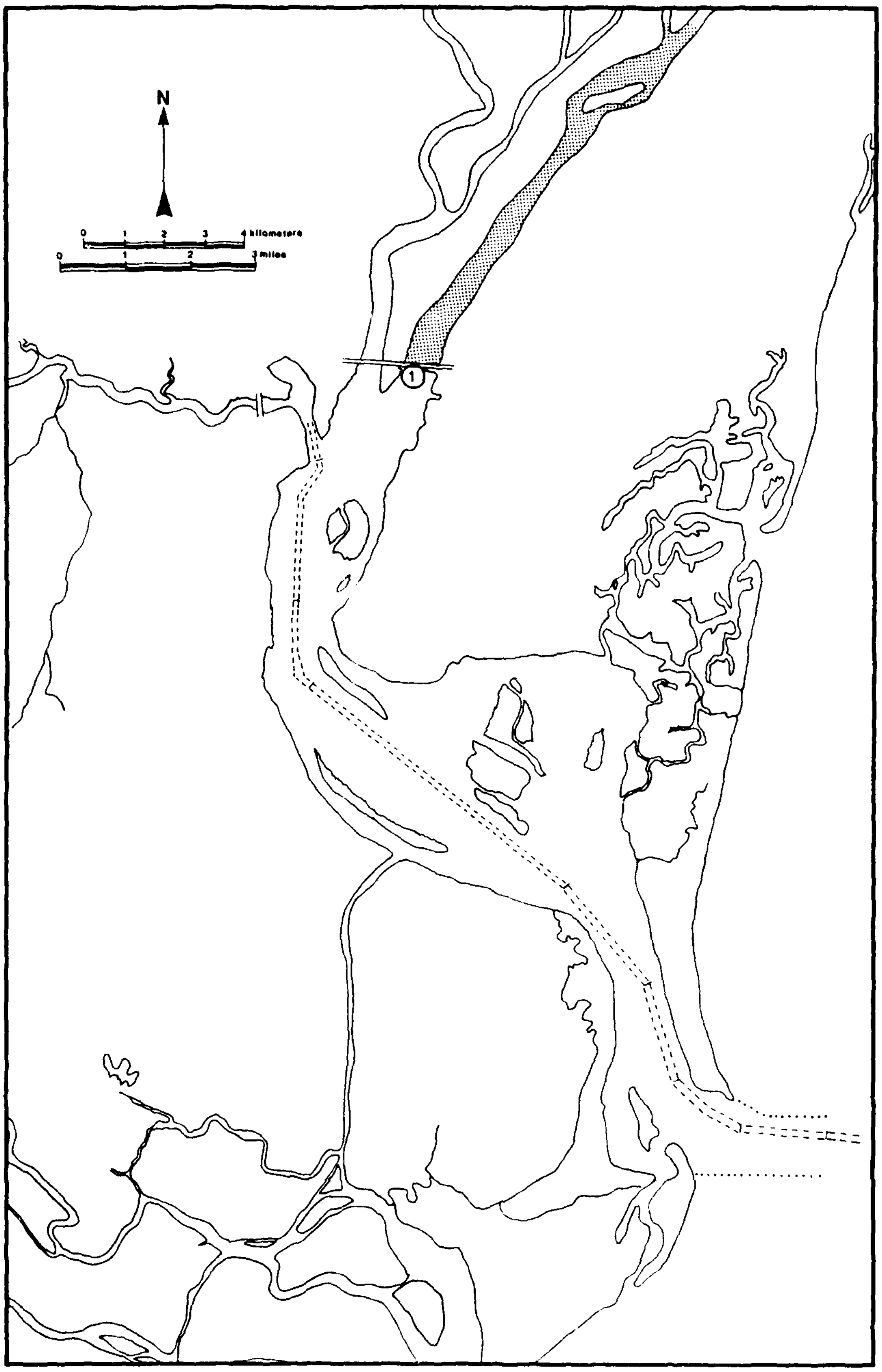

Figure VII.B-3. Anticipated areal extent of oil coverage for Case 1.

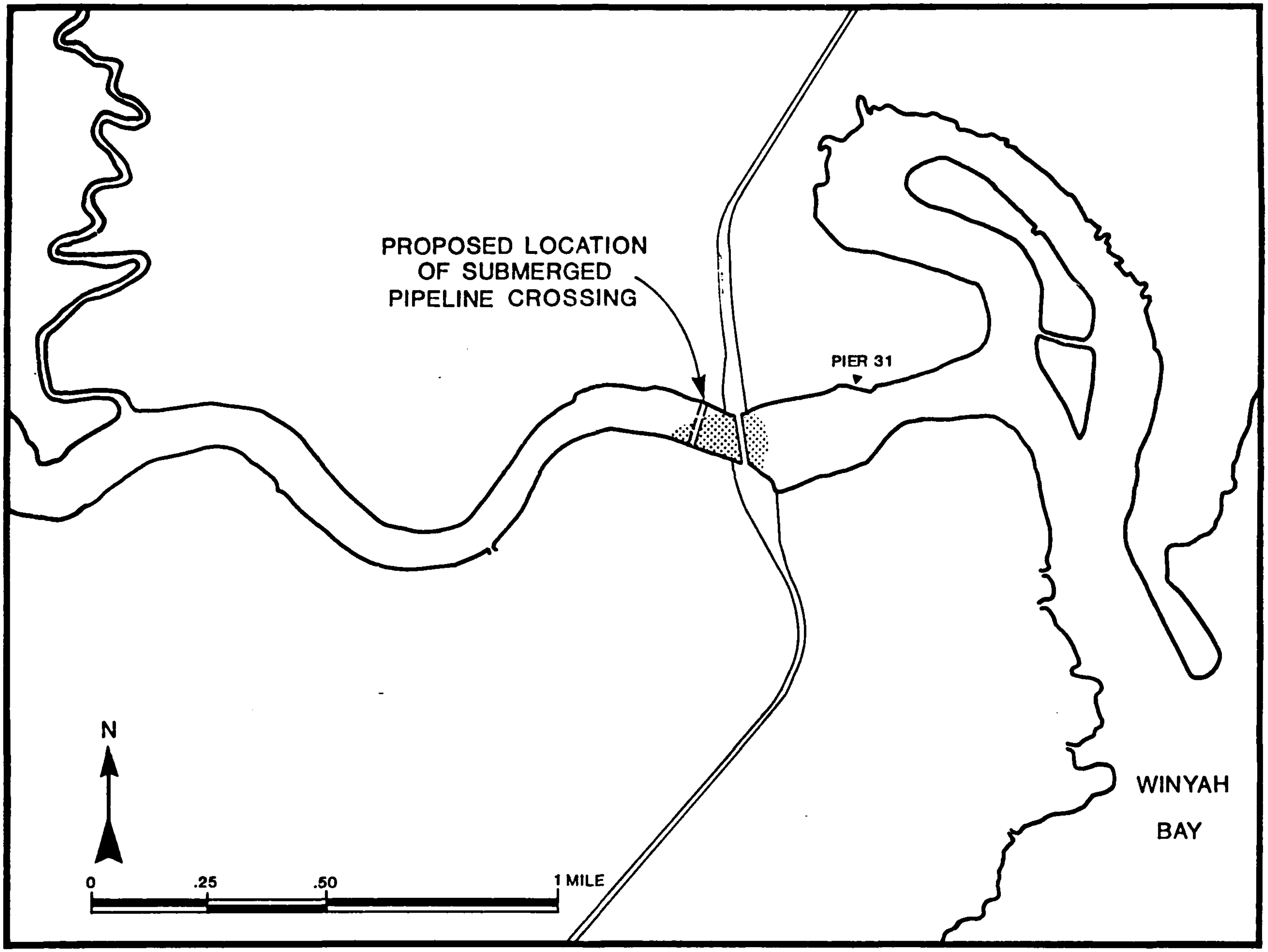

Figure VII.B-4. Anticipated areal extent of oil coverage for Case 2.

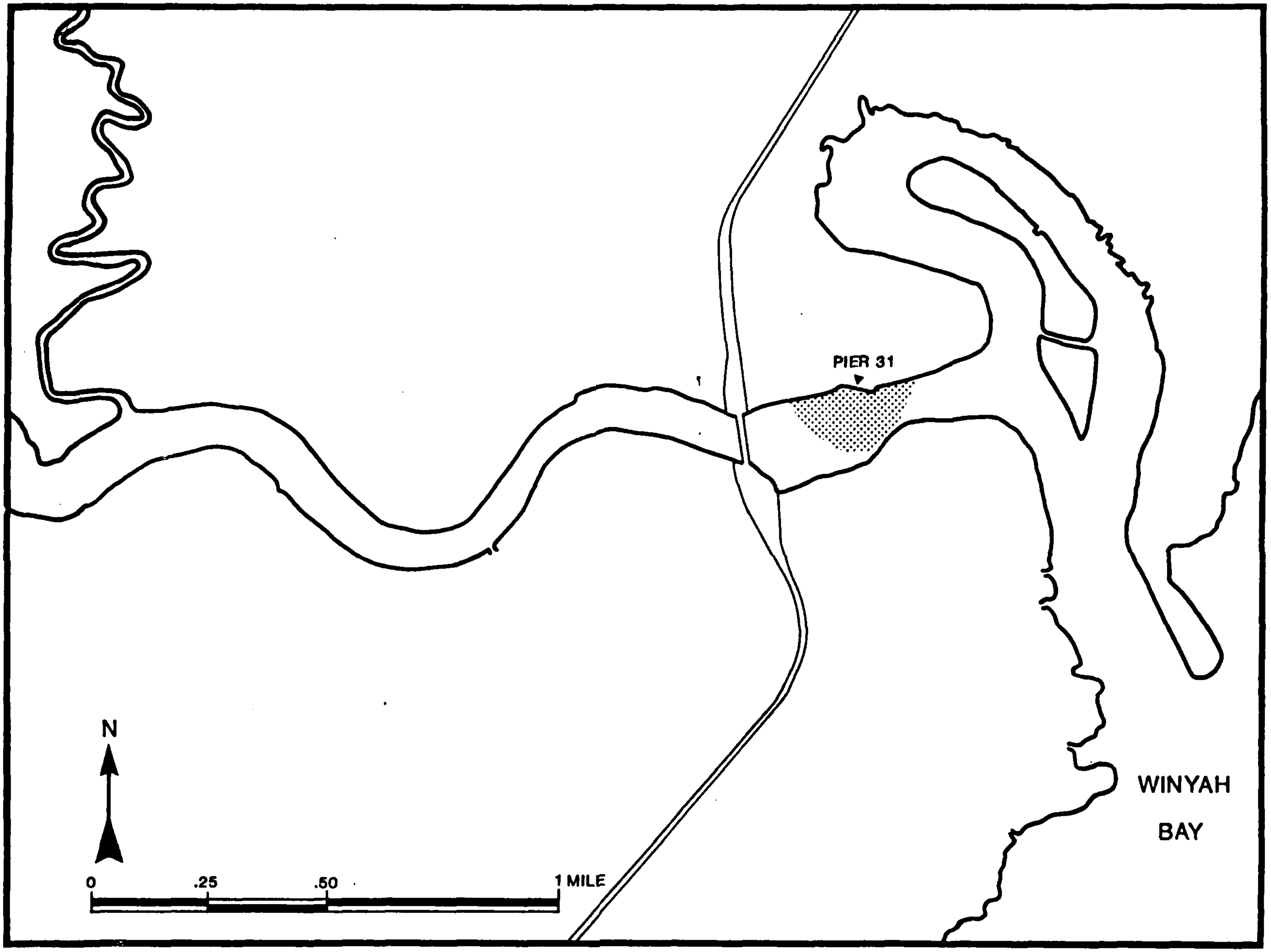

Figure VII.B-5. Anticipated areal extent of oil coverage for Case 3.

of the fouling is indicated on Figure VII.B-6. Although not depicted in Figure VII.B-6, it is possible some of the spill could be carried further up the Sampit River on flood tide. An operational spill of this magnitude is estimated in the Muga analysis to have a return interval of 7.2 months.

(v) Case 5. This analysis is for a loss of 1,218 barrels of crude oil at Pier 31. The TRAM analysis of Davis and Floyd, Inc. indicated a spill of this volume at the pier. A gentle breeze from the east was used in the analysis in order to determine the maximum extent to which oil would penetrate the Sampit River. Wind and flood tidal currents may be expected to move the front of the spill six km (3.7 mi) to the vicinity of Pennyroyal Creek. Bends in the river limit the effect of wind transport and serve to accumulate oil. Timely deployment of containment devices could prevent Winyah Bay from receiving major oil fouling, although it could be expected that some oil would penetrate into upper Winyah Bay. The extent of oil coverage in the Sampit River is indicated in Figure VII.B-7. According to the TRAM and Muga analyses, a spill of this magnitude has an estimated return interval between 19.3 and 27 years.

(vi) Case 6. This anlysis is constructed around a scenario presented by the USCG Marine Safety Office (Schiro, personal communication, 1984) as being the most probable "worst case" situation. Even so, they did not believe it to be a very probable occurrence. The spill is hypothesized to occur as a result of a fire/explosion on a tanker during unloading operations at Pier 31. There are many features of modern tankers, such as inert gas systems, which have substantially reduced the incidence of this type of casualty. If, however, a fire/explosion should occur, the Marine Safety Office felt that a maximum of 30 percent of the vessel's total capacity, or 42,000 barrels, would be released to surface waters. While it is certainly conceivable that the entire contents could be lost through such an event, this scenario will be based upon this more probable amount. Such a spill has been modeled for average river discharges and gentle winds from the northwest. The event occurs at mid-ebb tide, which encourages movement out of the Sampit River and into Winyah Bay in little more than one hour following the spill. Due to its large size, the spill almost immediately would span the width of the Sampit River. The oil would discharge into Winyah Bay, fouling the western shore around Sampit Point. The centroid of the spill would reach the northwestern shore of Rabbit Island after four hours at slack ebb tide. By this time, Rabbit and Hare Islands would be engulfed in oil and the shore of Waccamaw Neck would receive fouling from the vicinity of Horse Island northward to the Belle W. Baruch Forest Science Institute. With the change of tide, the floating oil mass would move northward along the shoreline of Waccamaw Neck and also back up into the Sampit River, possibly as far as Pennyroyal Creek. The prevailing northwesterly wind may serve to keep oil from the western shore of Winyah Bay at this time; however, the large oil mass would substantially cover the width of Winyah Bay. Eight hours after the spill occurs, oil would enter the Waccamaw River. Upstream movement would be limited to the vicinity of the Harrell Siau Bridge by the end of the flood tide cycle, eleven hours after the spill takes place. The extent of oil coverage at this time is shown on Figure VII.B-8. Subsequently, oil gradually would be flushed out of the Sampit River and Winyah Bay. Due to the large volume of oil involved, minor fouling may be detectable extensively throughout the bay with the actual locations dependent upon wind conditions. Based upon the probability methods of Muga, this spill falls within the size range categorized as catastrophic and has an estimated return interval of 284 years.

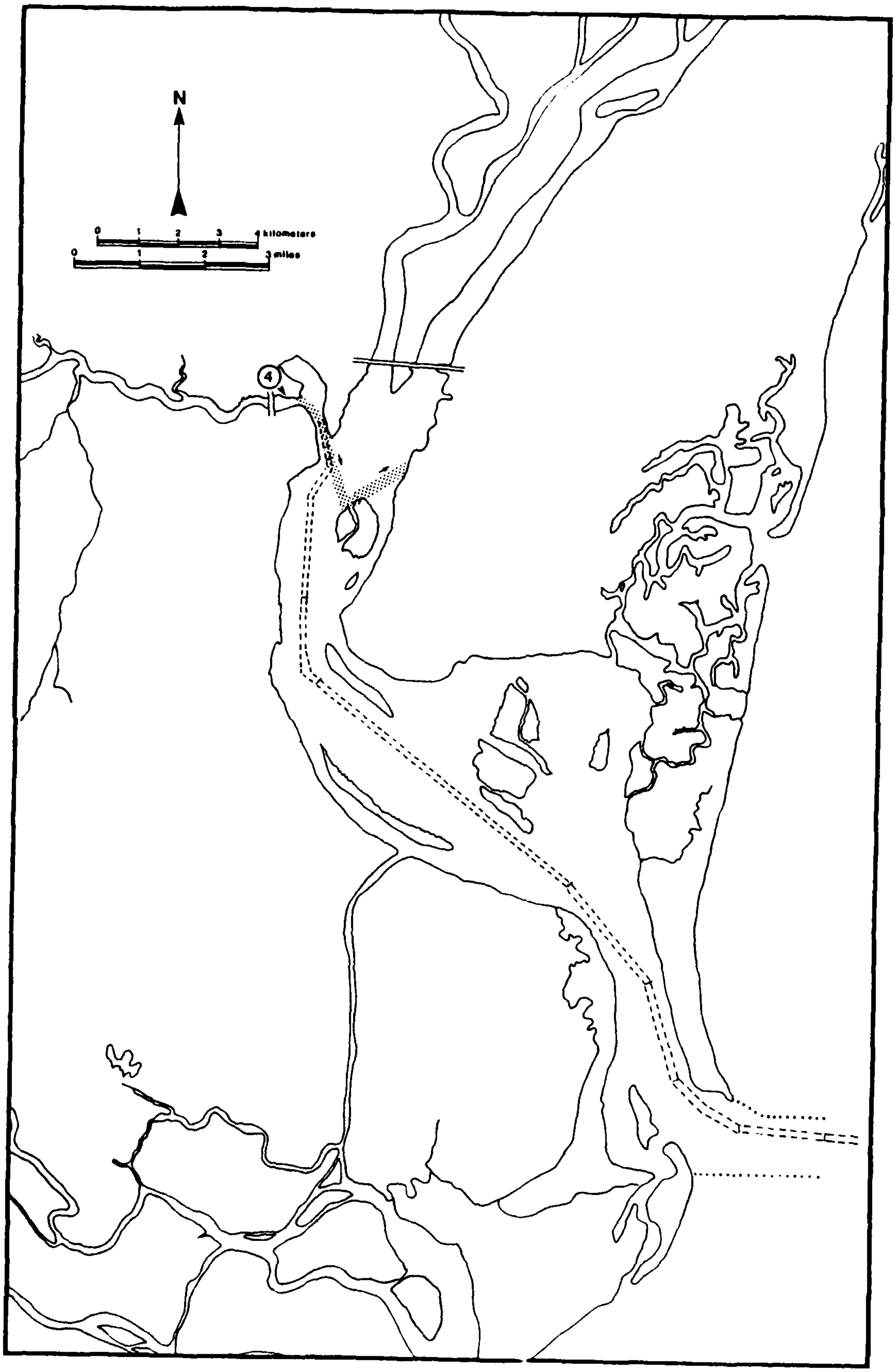

Figure VII.B-6. Anticipated areal extent of oil coverage for Case 4.

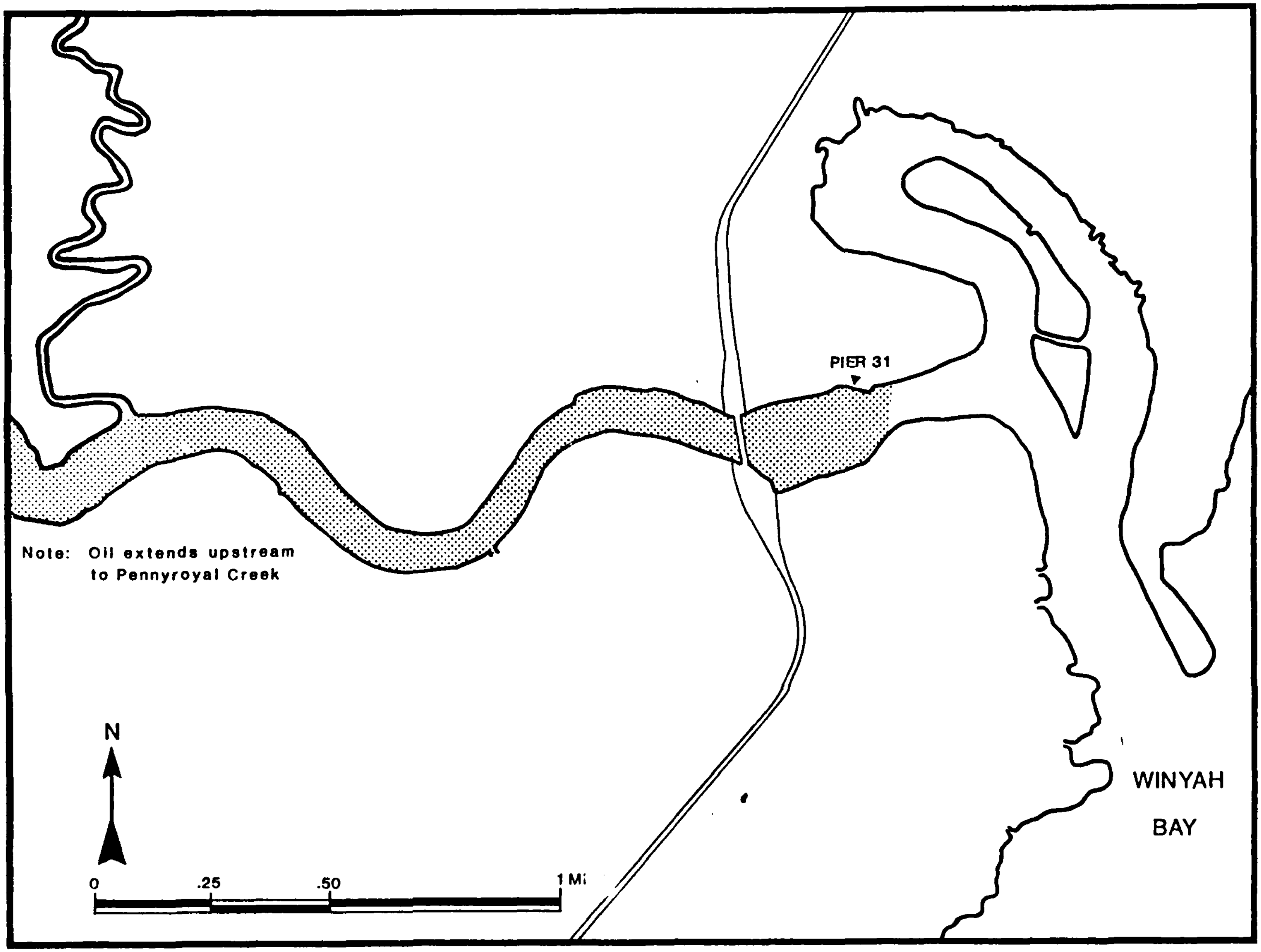

Figure VII.B-7. Anticipated areal extent of oil coverage for Case 5.

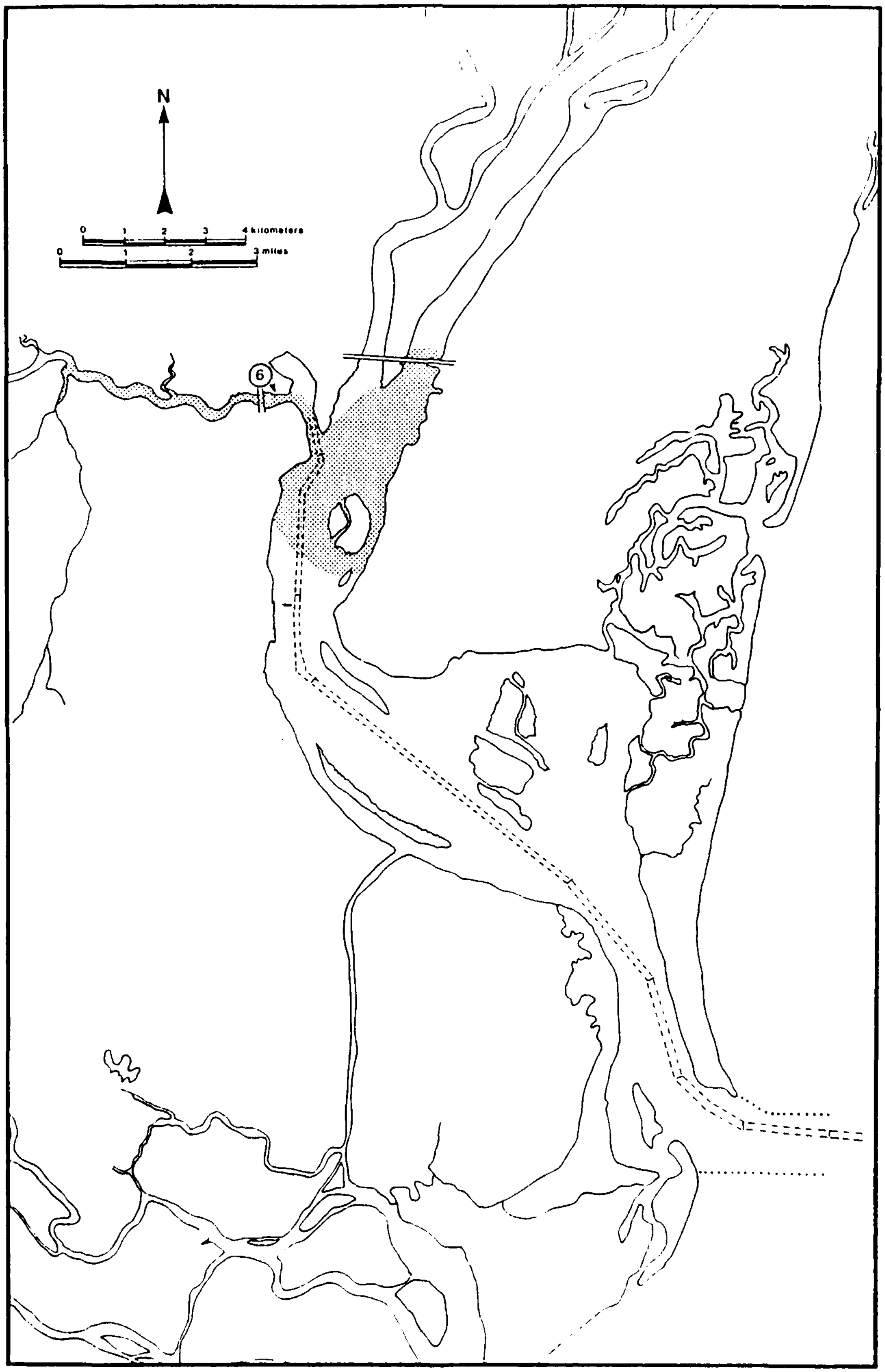

Figure VII.B-8. Anticipated areal extent of oil coverage for Case 6.

(vii) Case 7. This analysis is for a crude oil spill off Sampit Point of 2,277 barrels - the most probable volume for a non-catastrophic spill in Winyah Bay as predicted by the TRAM model analysis of Davis and Floyd Engineers, Inc. Modeling was conducted for a gentle northeasterly wind and a combined river discharge of 274 m^3/sec (9,675 cfs), which represents the average flow for October. The spill occurs at slack high tide. The effect of the wind would be to drive the spill ashore near Sampit Point while the receding tide would help carry oil southward. Thus the oil from this relatively small spill would coat the shoreline of Winyah Bay from Sampit Point to south of Belle Isle Gardens. Modeling indicates the spill front would reach the vicinity of the Western Channel by the end of the ebb tide, this being the likely southward limit of oil penetration as a slick. Oil entrainment upon the shoreline may prevent substantial amounts of oil from remaining afloat at this time. The extent of oil coverage at slack ebb tide is shown in Figure VII.B-9. Future oil movement would depend upon physical conditions. If the wind remains out of the northeast, oil would be essentially grounded. As the wind shifts to blow from the west, oil may be remobilized, causing fouling of other portions of Winyah Bay. Based on the TRAM and Muga analyses, the return interval for this spill is estimated to be between 19.3 and 27 years.

(viii) Case 8. This scenario describes the effects of the total cargo loss of an Intracoastal Waterway barge off Sampit Point. Physical conditions have been selected to determine the maximum extent of oil slick movement into the Pee Dee River. A low river discharge of 84.9m^3/sec (3,000 cfs) combined with a strong southerly wind and flood tide provide strong current vectors to promote northward movement of the slick. The slick enters the Pee Dee River 135 minutes after its initiation. The model at this point does not include the wind factor; however, in some cases wind would obviously be important. Without considering wind, the spill would travel upstream to a point 3.1 km (1.9 mi) above Km 0 of the Pee Dee River, almost to the confluence of the Black River. If wind were to be considered, it could add 13.6 km (8.5 mi) to the distance. Of course, the channel of the Pee Dee/Black Rivers does not run straight; thus, the wind would tend to run the spill aground at bends of the river. Conceivably a spill could be blown a significant distance up the Waccamaw due to the straightness of its lower course, but this would require an optimum set of conditions. In realistic terms, the wind would not add significantly to the upstream excursion of the oil slick beyond that due to tidal currents alone. Figure VII.B-10 indicates the likely extent of surface oil movement. It may be noted that oil is not shown entering the Waccamaw or Sampit Rivers, although under a more westerly wind it is likely that the Waccamaw River would receive fouling and the flood tide could carry oil into the Sampit River.

However this is not the end of this scenario. Johnson (1970) estimated that the salt water interface could reach to Mile 16 on the Pee Dee and Waccamaw Rivers and to Mile 13 on the Black River. Johnson (personal communication, 1984) explained that at high slack tide the saltwater is pushed to its maximum upstream position and streads out into the bordering salt marsh. On the ebb tide, the channel proper is flushed by the downstream flow of river water, but a portion of the salty water is stranded in the marsh. During the next flood tide, this salty water is carried farther upstream, diluted, and again stranded in the marshes. By this process, the salty water can be carried upstream to the point of equilibrium noted above as the saltwater interface. This point would vary with streamflow conditions.

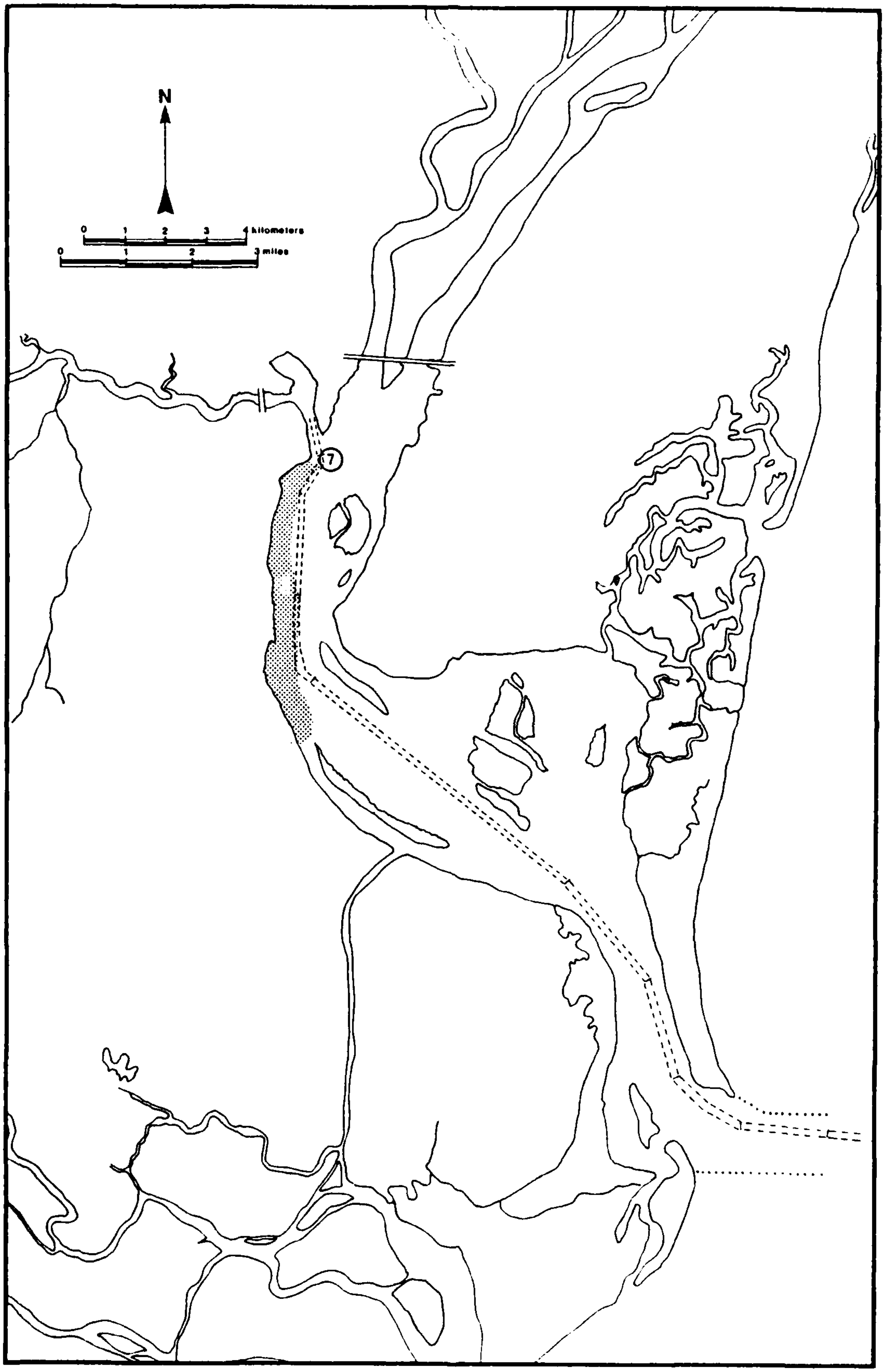

Figure VII.B-9. Anticipated areal extent of oil coverage for Case 7.

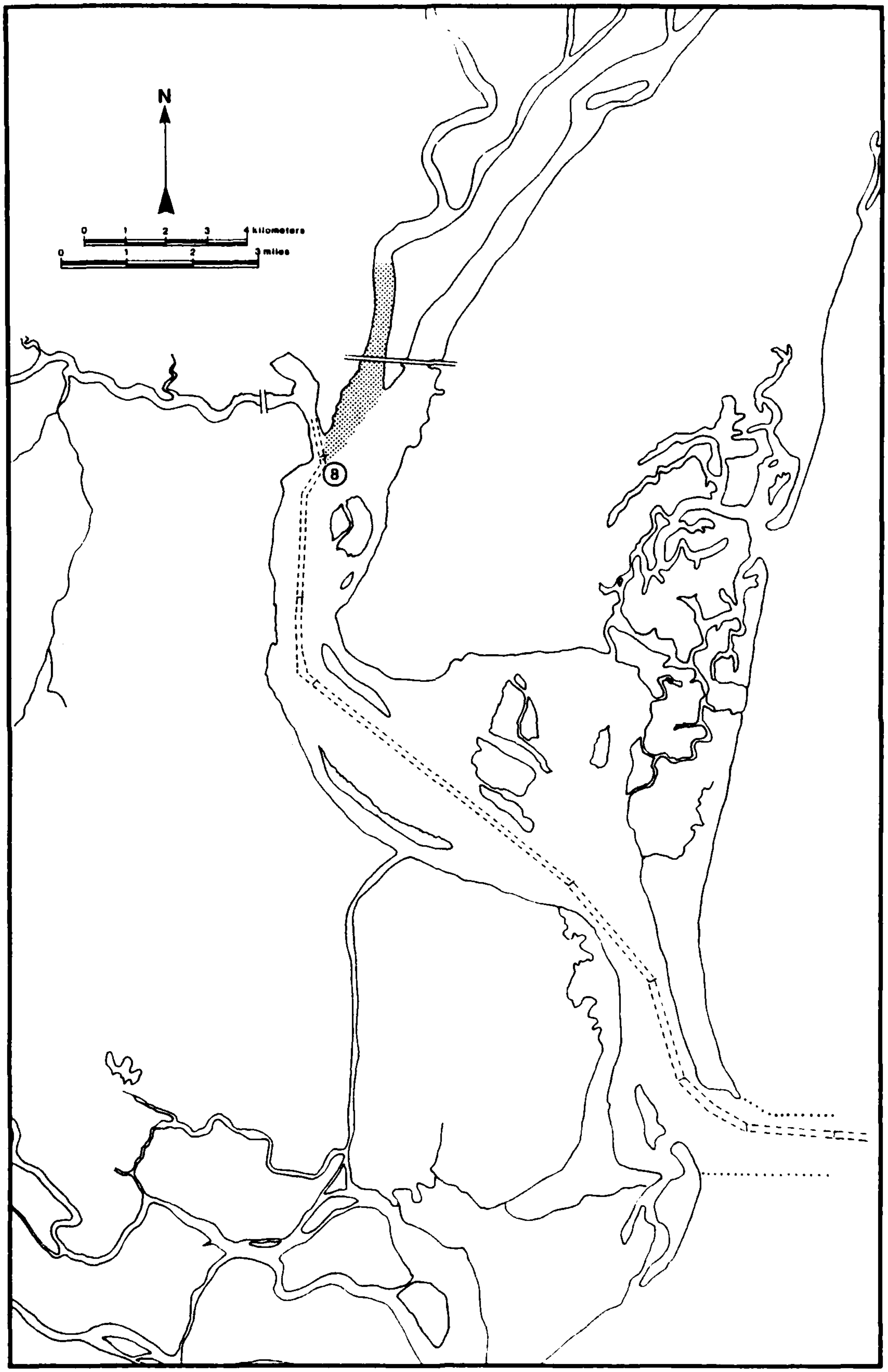

Figure VII.B-10. Anticipated areal extent of oil coverage for Case 8.

Thus it is conceivable that an oil spill would be similarly transported upstream beyond a point that might be indicated by a single tidal cycle. The oil also could be temporarily stored in the marsh bordering the river and be carried farther upstream by successive tides, albeit in diluted state.

This spill of 17,000 barrels of refined product falls within Muga's catastrophic category with an estimated return interval of 285 years.

(ix) Case 9. This total loss spill occurs at the convergence of the western channel (Intracoastal Waterway) and the Winyah Bay channel. Traffic control at this point in Winyah Bay Harbor relies on a passive system, i.e., bridge to bridge communication between barge and tanker (Shiro, personal communication, 1984). Although the likelihood of a total cargo rupture anywhere in the harbor is small, a Georgetown harbor pilot (Doyle, personal communication, 1983) pointed out this location as having a somewhat increased likelihood of a barge/ship collision. Thus, in addition to a total loss of crude oil cargo, the worst case would cause an additional loss of 17,000 barrels of refined product from the barge. The model was run for a combined river discharge of 113 m^3/sec (3,990 cfs), which is a low flow for June. An extremely strong southwest wind and a flood tide add to give a combination of physical conditions that would maximize the effects of the spill on the river system feeding Winyah Bay.

A spill at this location would move up Winyah Bay channel in the direction of Rabbit and Hare Island, making first landfall on the western shore of Rabbit Island approximately one hour after occurrence. After two hours, the slick would affect the mouth of the Sampit River and, after three hours, the slick would have entered the mouths of the Pee Dee and Waccamaw Rivers, covering both the western shore of Waccamaw Neck and the eastern shore of Georgetown.

Much of the spill is grounded on Rabbit Island. A good portion of the remainder enters the mouths of the Waccamaw and the Pee Dee Rivers.

Before the tide changed, the slick would cover both the eastern and western shorelines of Winyah Bay above Frazier Point, probably surrounding Rabbit and Hare Islands. Oil from this spill could follow the freshwater/saltwater interface up the Sampit River to Pennyroyal Creek, and up both the Pee Dee and the Waccamaw Rivers to the same extent as Case 8. Figure VII.B-11 indicates the extent of oil coverage on the initial flood tide.

When the tidal cycle changes and the mass of oil above Frazier Point moves down Winyah Bay it is likely to foul Belle Isle Gardens, Esterville Plantation, the Intracoastal Waterway, the western shore of Marsh Islands, Cat Island, and North and South Islands as it moves through Winyah Bay Channel toward the mouth of the harbor. With the ebbing tide, oil is likely to move into the Intracoastal Waterway and Mosquito Creek as far as tidal movement will permit. Mud Bay, including the northern shore of Pumpkinseed Island, may receive minor fouling.

Although a barge/ship collision at the channel convergence resulting in total cargo loss of both vessels is clearly possible, the probability of its occurrence is extremely low. An estimate of return interval cannot be made directly from the analyses reviewed in the previous section, but the inference can be made that the return interval would be in excess of 357.1 years.

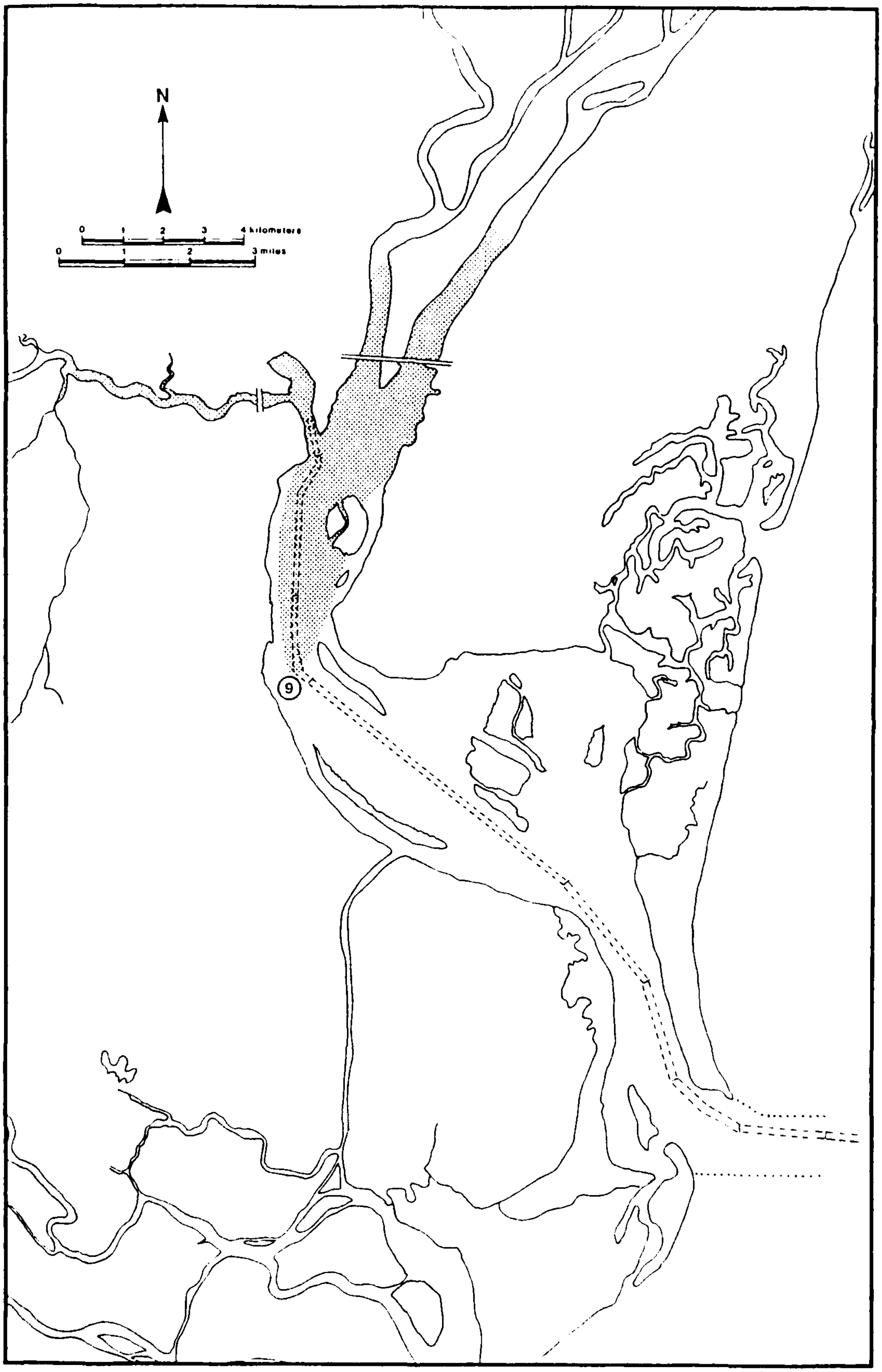

Figure VII.B-11. Anticipated areal extent of oil coverage for Case 9.

(x) Case 10. This spill of 1,700 barrels of refined product results from the grounding of a barge in the Intracoastal Waterway midway between the Western Channel and Minim Creek. The spill occurs at slack high tide with no wind to affect the oil slick. Pollutant would quickly foul the breadth of the waterway and the ebb tide would move oil into Minim Creek, Big Duck Creek, the North Santee River and North Santee Bay. The extent of coverage by the end of the ebb tide is shown in Figure VII.B-12. Upon the change to the flood tide an indeterminate quantity of oil would move north in the Intracoastal Waterway to enter Winyah Bay at the Western Channel. Oil would also move up the North Santee River and penetrate the creeks in that vicinity. Based on the TRAM and Muga analyses, the return interval for this spill is estimated to be between 19.3 and 27 years.

(xi) Case 11. This case discusses a 14,000 barrel crude oil spill occurring as a result of a tanker grounding in Winyah Bay Channel off the mouth of Mosquito Creek during flood tide. A moderate wind from the east would push the slick onto the shore of Cat Island and into the Western Channel. Oil would reach the Intracoastal Waterway in about two hours and possibly reach Esterville Plantation by high tide. During the ebb tide there is a net movement of water southward through the Intracoastal Waterway and this may be expected to suck oil from the Western Channel into the waterway. Any reduction in the wind vector from the east would assist seaward movement of the slick. This is likely to span the width of the bay at the bottleneck beyond Mosquito Creek. Figure VII.B-13 indicates the extent of oil coverage on the initial flood tide cycle. A spill of this magnitude falls within Muga's catastrophic category with an estimated return interval of 285 years.

(xii) Case 12. This spill occurs in Winyah Bay Channel, 0.7 km (0.4 mi) south of Georgetown Lighthouse. Although a tanker would not normally be found in the navigation channel other than at high tide, this analysis assumes that an instantaneous release of the entire cargo occurs at slack low tide after a tanker runs aground. As such, the probability of this spill occurring is extemely low. The light breeze from the southeast provides ideal conditions for movement of the oil into Winyah Bay on the rising tide. Within an hour, oil would entirely cover the bay at the narrows between North Island and Cat Island. After two hours the leading edge of oil would enter the lower reaches of Mud Bay. The combination of tidal, wind and river currents is such that the slick does not follow the navigation channel toward Georgetown but is entirely routed into Mud Bay. At high tide, the oil would have penetrated deeply into Mud Bay, inundating Pumpkinseed Island and reaching Jones Creek. The eastern shore of Marsh Islands would have received fouling but the presence of the Marsh Islands would prevent oil from moving westward. The changing tide would arrest the movement of the oil before it reaches the shoreline in the vicinity of No Man's Friend Creek and Haulover Creek. Figure VII. B-14 indicates the extent of oil coverage at high tide. On the subsequent ebb tide, the shoreline of South Island and Mother Norton Shoal would be affected. From the Muga and TRAM analyses, the return interval for a total cargo loss of 140,000 barrels is estimated to be between 284 and 357.1 years.

(xiii) Case 13. This relatively small spill of 2,690 barrels occurs at slack low tide in the mouth of Winyah Bay. A moderate wind from the south would combine with the flood tide to form a long, narrow ribbon of oil hugging the western shore of North Island and extending into Mud Bay as far as Cottonpatch Creek. Pumpkinsed Island may possibly be affected. During its northward passage the bulk of oil would become immobilized at the shoreline. On the outgoing tide, the remainder of the slick would possibly have dispersed enough to foul South Island. Figure VII.B-15 indicates the initial extent of oil coverage on

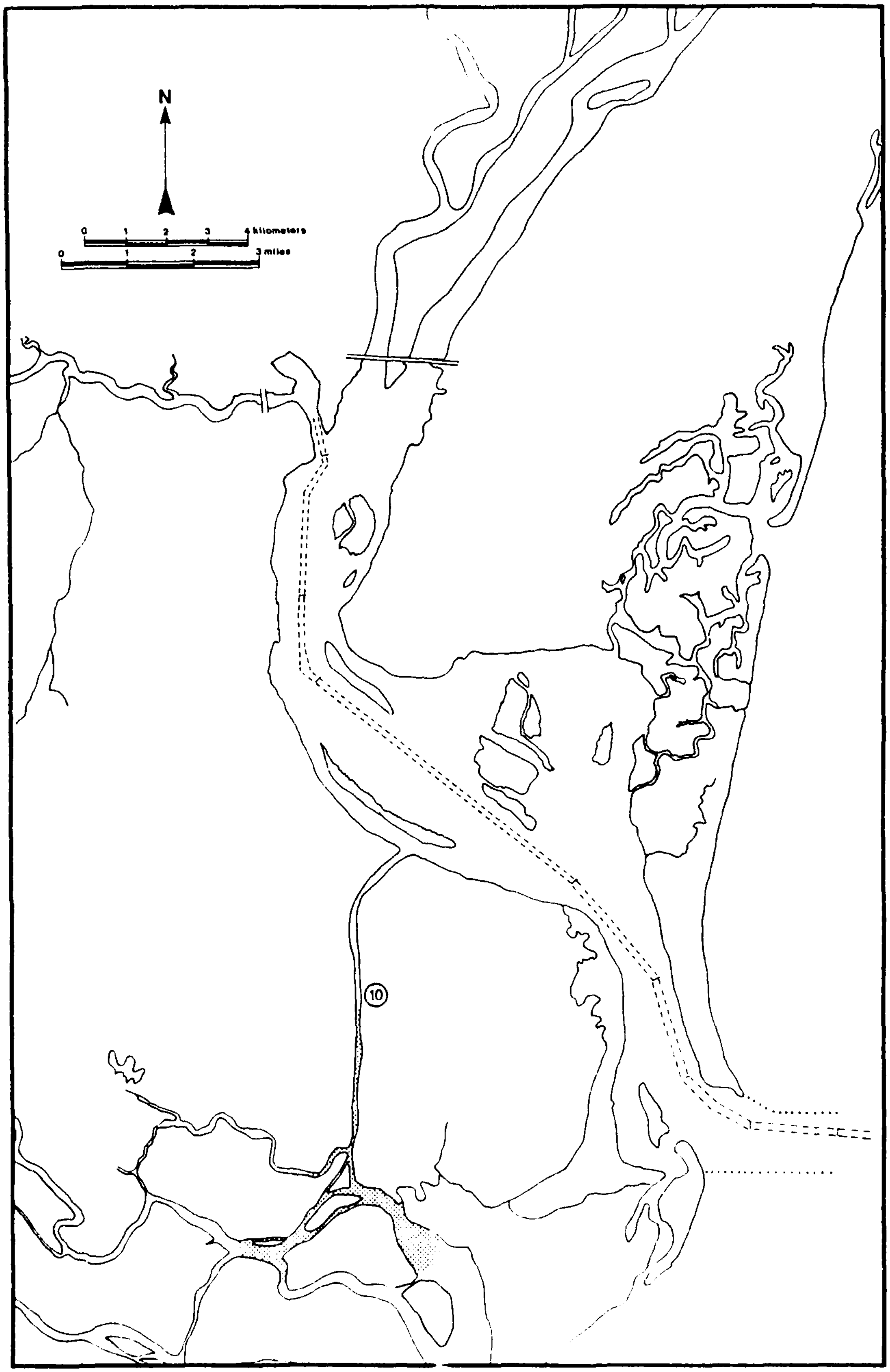

Figure VII.B-12. Anticipated areal extent of oil coverage for Case 10.

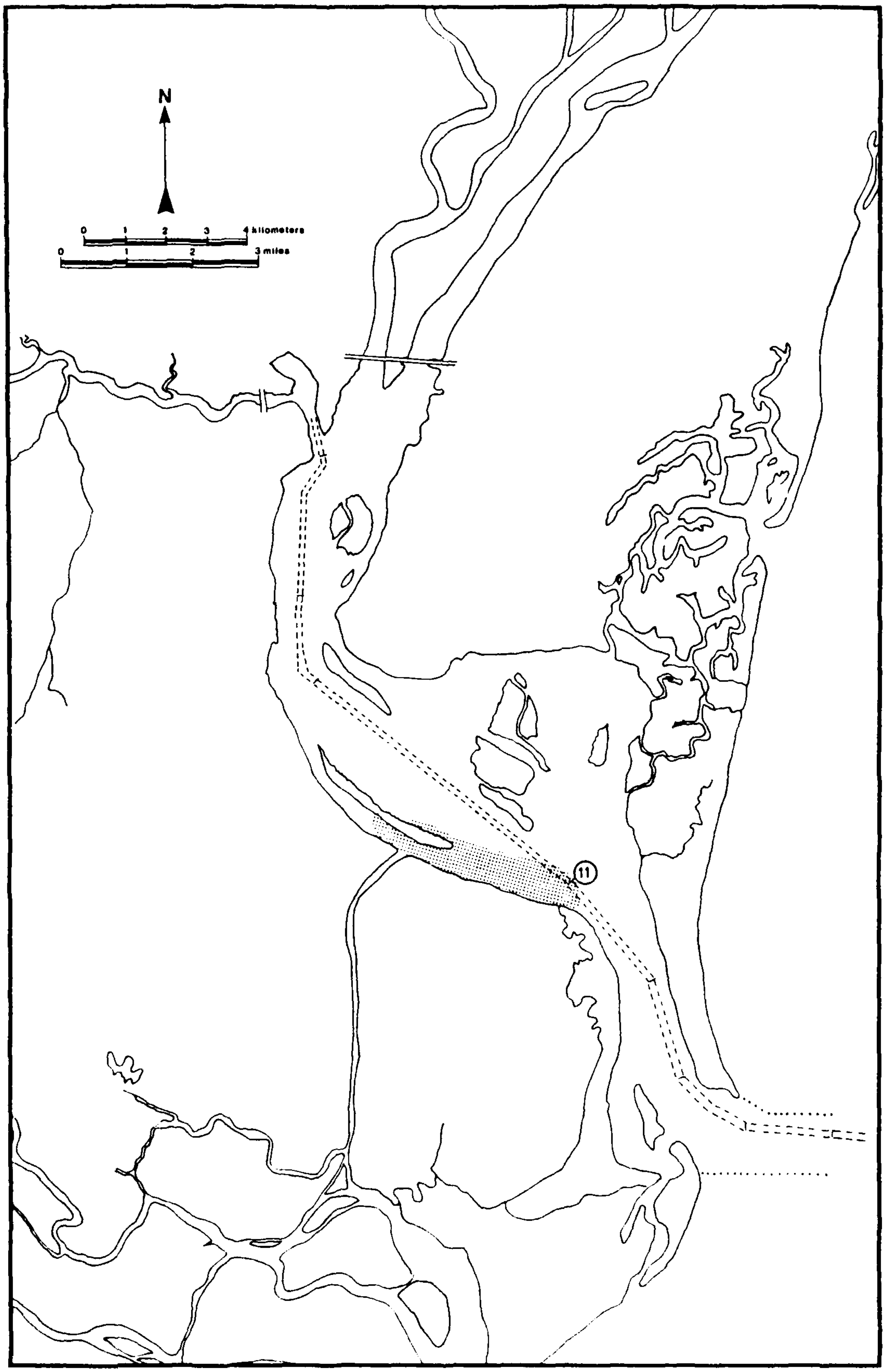

Figure VII.B-13. Anticipated areal extent of oil coverage for Case 11.

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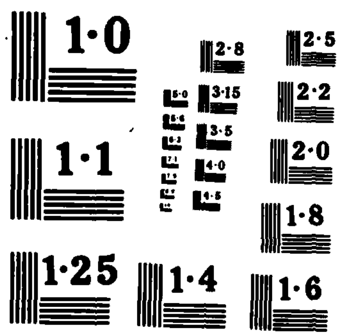
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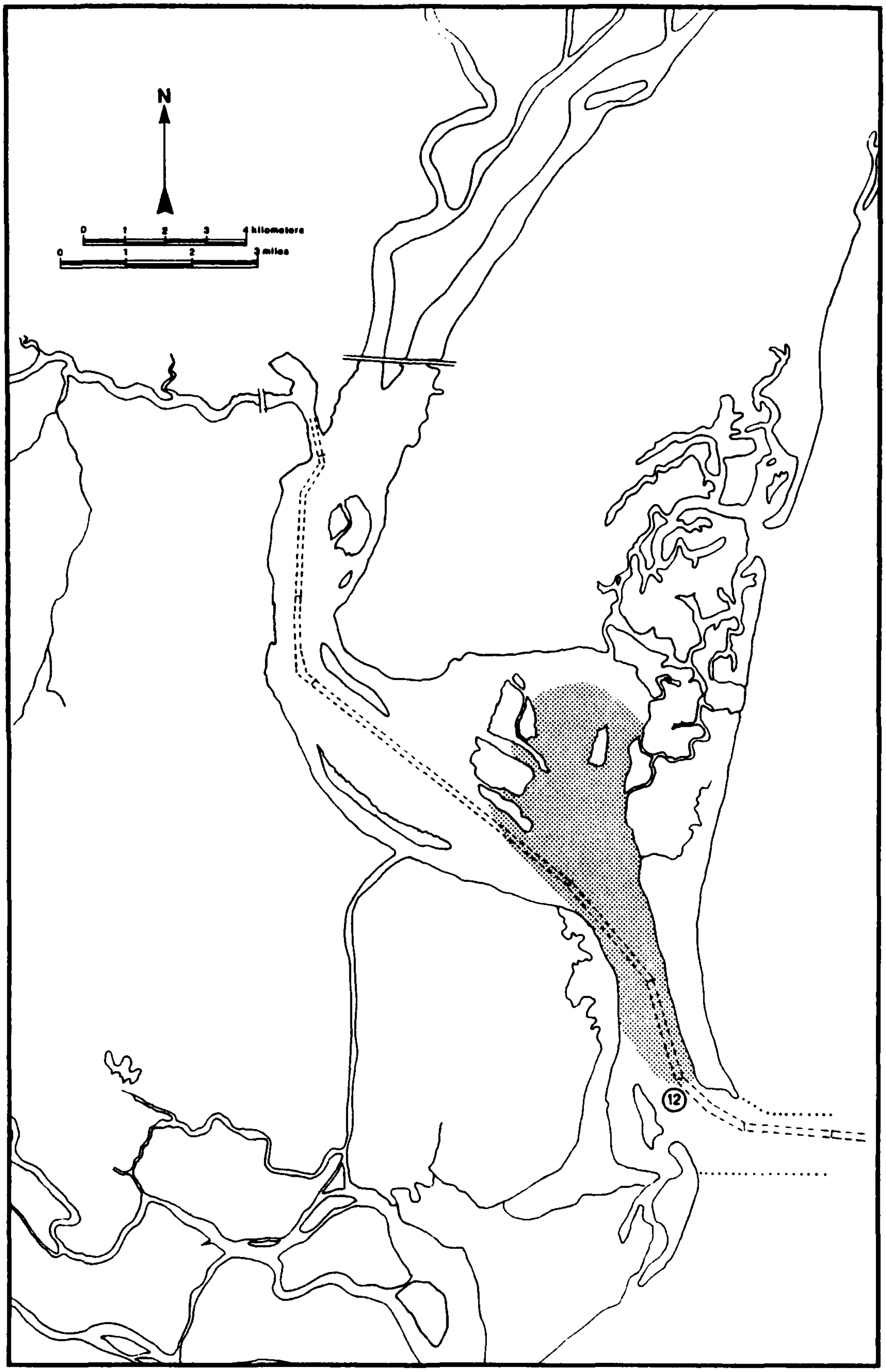

Figure VII.B-14. Anticipated areal extent of oil coverage for Case 12.

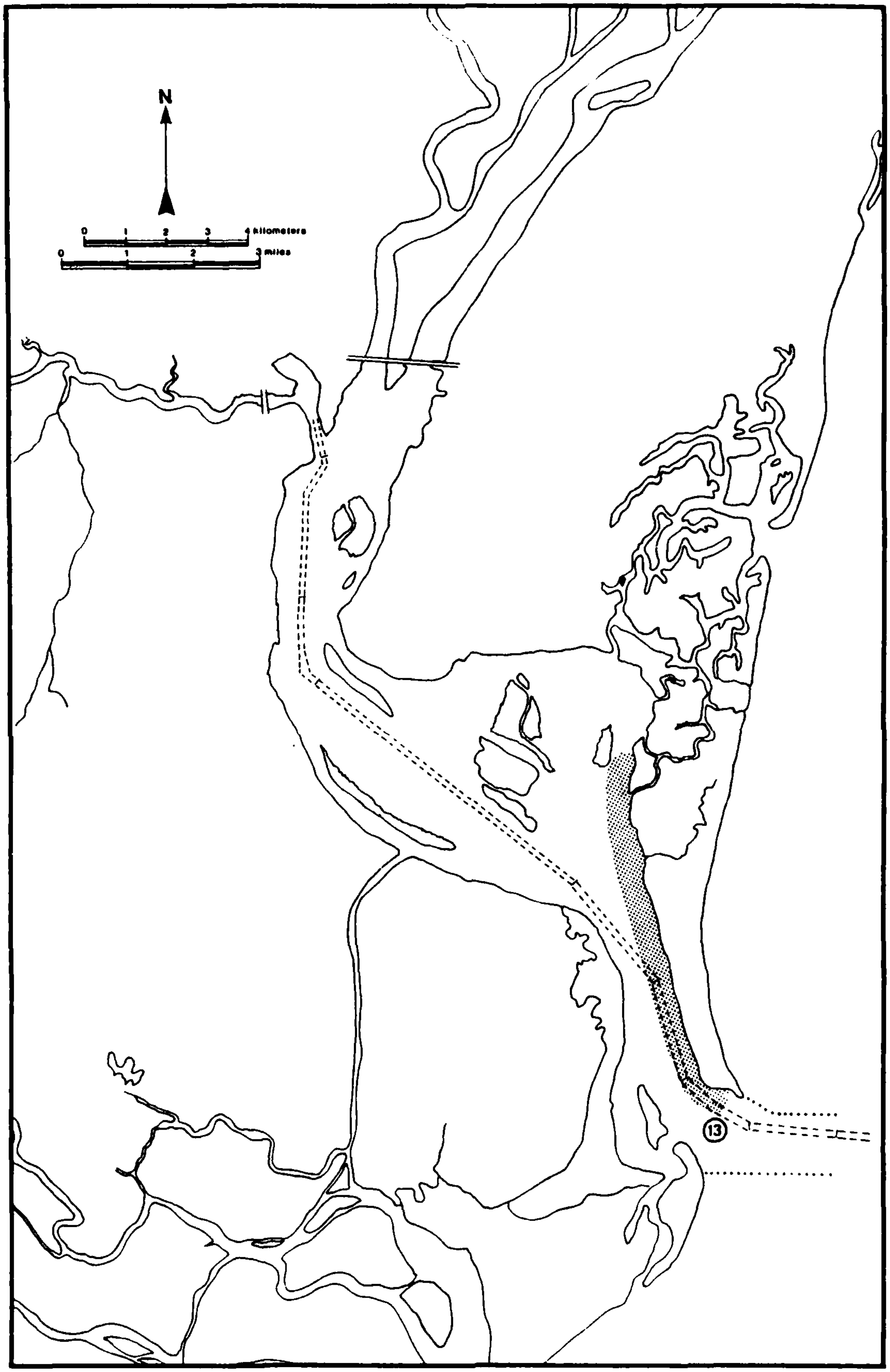

Figure VII.B-15. Anticipated areal extent of oil coverage for Case 13.

the flood tide. From the Muga and TRAM analyses, a spill of this magnitude would have an estimated return interval between 19.3 and 27 years.

(xiv) Case 14. The circumstances of this spill are based on comments by Cmdr. Schiro (personal communication, 1984) indicating that, while unlikely, the most serious situation involving a collision between a loaded tanker and a fixed object would occur at the Winyah Bay entrance jetties during a flood tide. Schiro thought it unlikely that the damage sustained would involve more than one tank and estimated the cargo loss at 14,000 barrels. He felt this scenario to be "the most serious situation that could reasonably result from the proposed refinery's operation." The spill has been postulated to occur in December with a high combined river discharge of 99 m^3/sec (3,496 cfs). This substantial discharge effectively prevents oil from penetrating Winyah Bay beyond the narrows in the vicinity of Cat Island. Although the shorelines of the bay would not be entirely fouled on the flood tide, the ebb tide would reverse oil movement, causing sufficient spreading to foul both shorelines. Approximately five hours after the spill occurs the ebb tide would have returned the centroid of the slick to the vicinity of the accident and oil would be released into open coastal waters. Figure VII.B-16 indicates the extent of oil coverage by high tide. Fouling of Winyah Bay beyond this point could well be averted since sufficient time should enable the deployment of containment devices. The return interval for this spill would be estimated at 285 years, using the Muga analysis.

(xv) Case 15. This spill scenario and the following one investigate the likely effects of accidents in open water as tankers approach the Winyah Bay entrance. Case 15 analyzes a total loss spill occurring 7 km (4 mi) east of Winyah Bay entrance jetties at slack low tide. Strong winds from the northeast combine with the southerly ocean currents which exist in September and the rising tide to drive the oil slick ashore on South Island. Landfall should occur during the early portion of the next ebb cycle but the strong wind would keep the oil against the coastline as the slick continues to drift to the south. By slack low tide the spill centroid would be located off the mouth of North Santee Bay and the subsequent flood cycle may be expected to drive oil into the tidal inlets in the area, fouling adjacent marshland. Approximately 24 hours following the spill the shoreline fouling should extend from South Island to Cape Romain, as shown in Figure VII.B-17. Total cargo loss spills near the mouth of Winyah Bay are applicable to both the TRAM and Muga analyses. Using these methods, the return interval for a 140,000 barrel spill can be estimated at between 284 and 357.1 years.

(xvi) Case 16. This scenario involves a total cargo loss occurring in the near coastal region 13 km (8 mi) east of Winyah Bay entrance. The spill occurs at slack low tide under a strong wind out of the southeast. The oil spill would be driven onto the shoreline at North Inlet, missing the entrance to Winyah Bay. It should take the slick 12 hours to reach shore, so it would reach the inlet about one full tidal cycle following the spill. This would coincide with the beginning of the rising tide and promote the entry of oil into the creeks and marshland behind North Inlet. Debidue Beach would receive fouling. Remobilization of oil and longshore currents could cause fouling of the shoreline for an indeterminate distance to the north. Figure VII.B-18 indicates the extent of oil coverage 12 hours after the spill occurs. As in Case 15, the estimated return interval for this total cargo loss spill would be between 284 and 357.1 years.

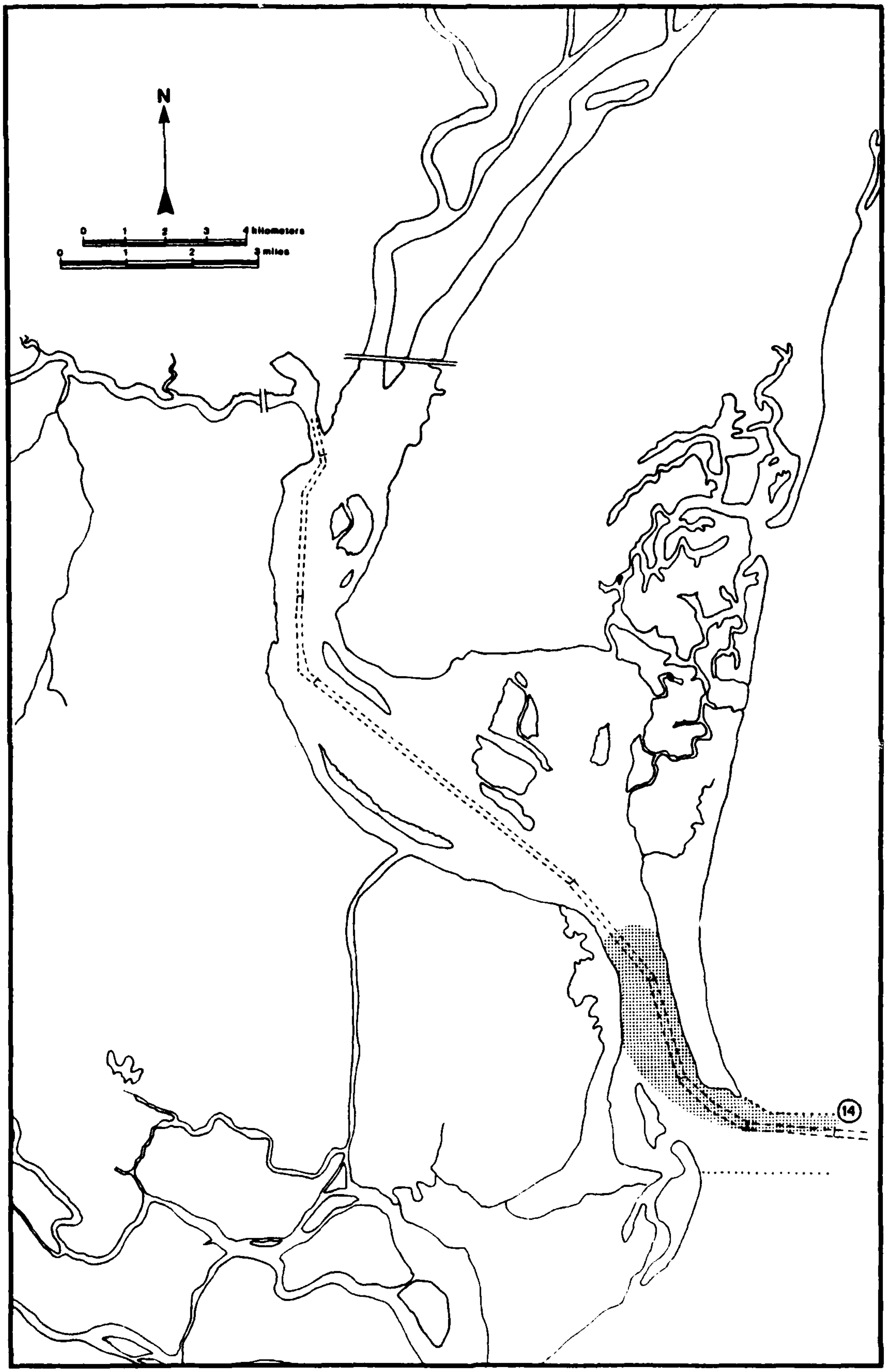

Figure VII.B-16. Anticipated areal extent of oil coverage for Case 14.

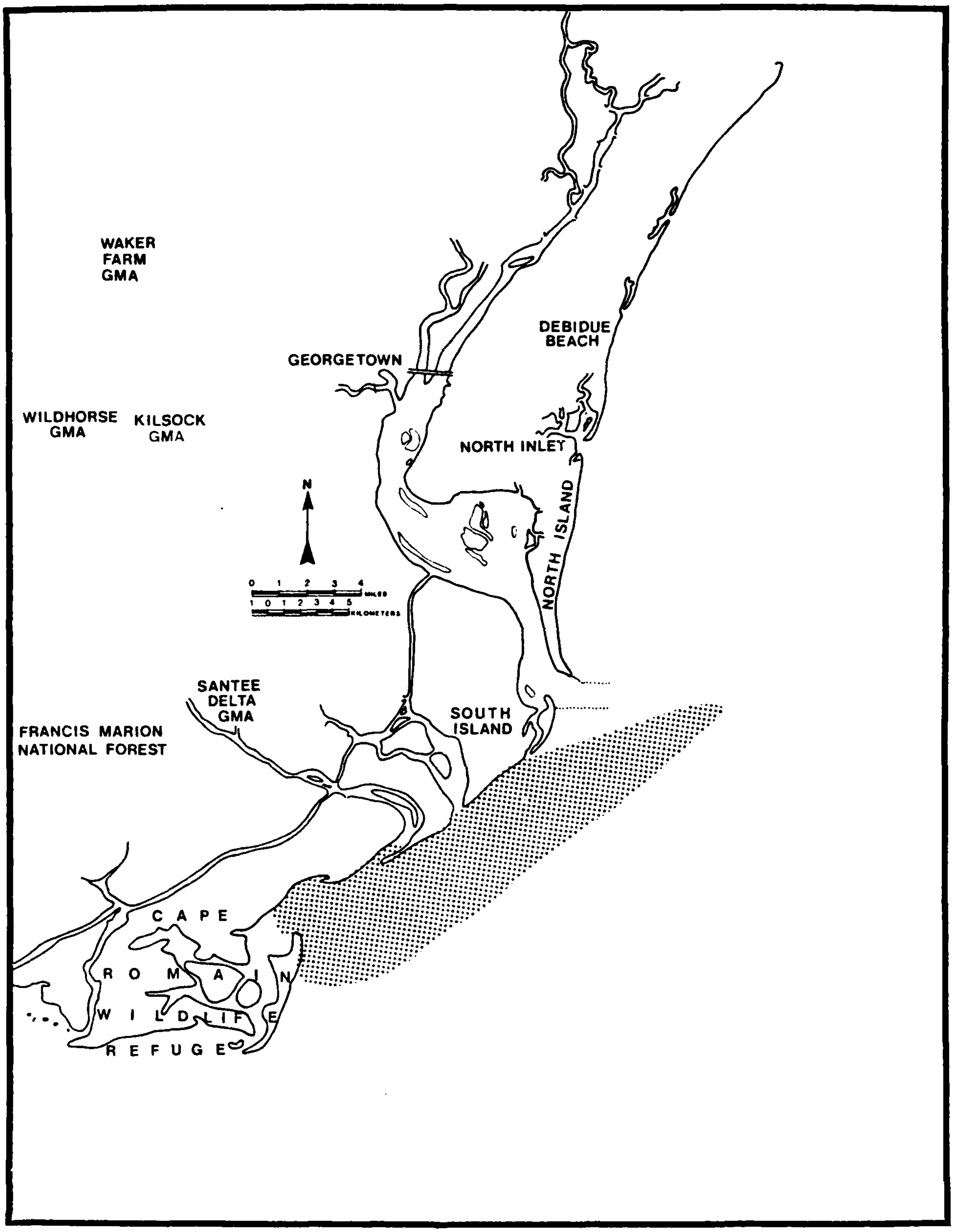

Figure VII.B-17. Anticipated areal extent of oil coverage for Case 15.

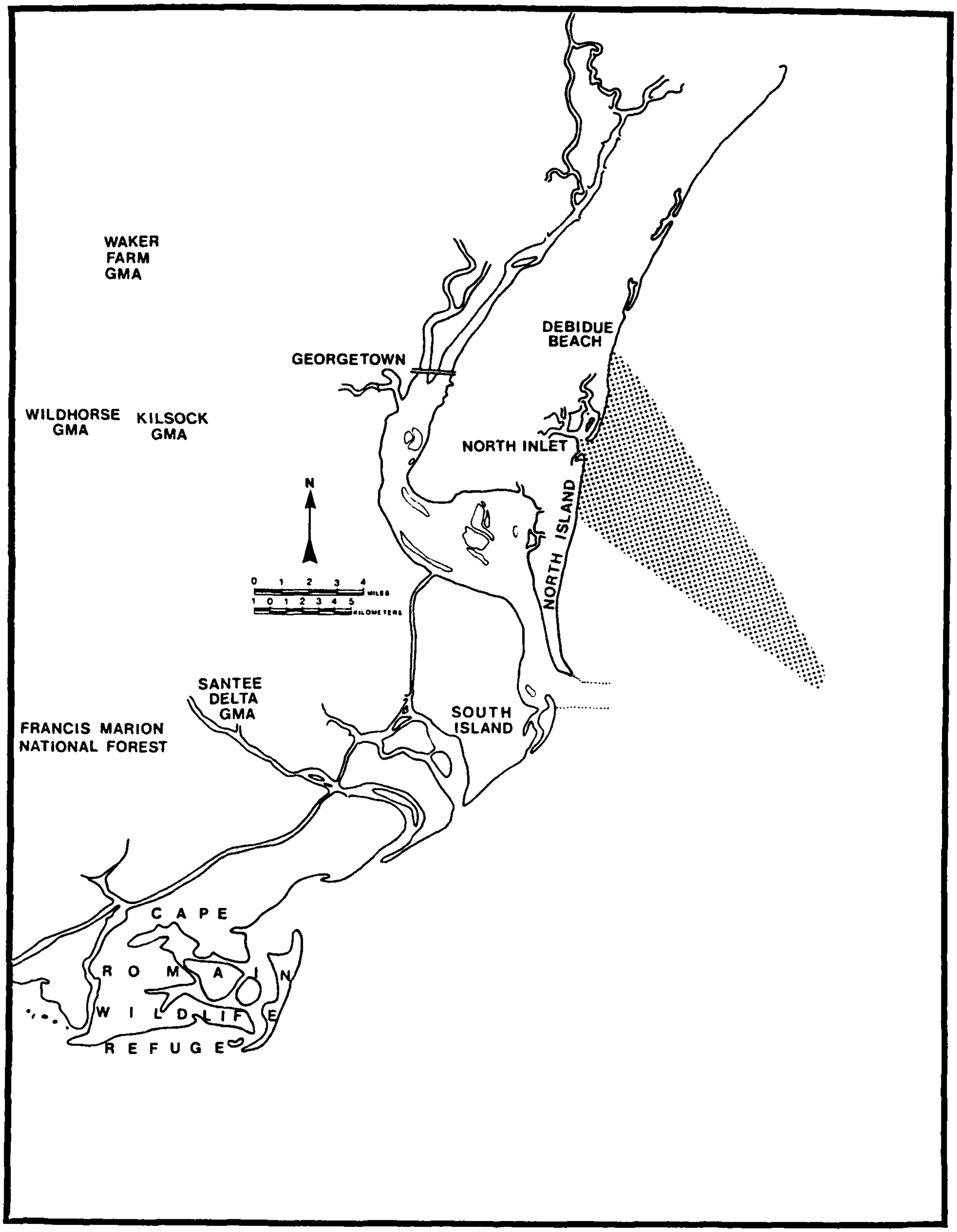

Figure VII.B-18. Anticipated areal extent of oil coverage for Case 16.

(xvii) Case 17. This scenario involves loss of refined oil from the tank farm associated with the proposed refinery located on the Harmony Plantation siting alternative. The loss occurs as a result of massive structural failure of tanks within the tank farm, most likely due to explosion. Although rather remote, this possibility does exist as evidenced by historic tank farm explosions in the United States. The applicant proposes dikes around storage tanks which would be capable of containing the entire volume of the largest tank in the enclosed area, as is required by 40 CFR 112 Section 112.7(e)(5)(iii)(B). This scenario assumes multiple tank ruptures in which the diked capacity is exceeded by 60,000 barrels. The immediate impact would be inundation of drainage areas, lowlands and marshlands surrounding the tank farm site, possibly including large portions of Turkey and Pennyroyal Creeks. A relatively direct route to the Sampit River could be assumed with a resultant inflow of about 40,000 barrels, one-third of the original overflow having been retained in transit to the river. The movement of the oil slick upon reaching the Sampit River would be very similar to Case 6 (previously discussed) so a separate figure is not provided here. The additional impacts for Case 17 would be extensive fouling of marshes and creeks near the Harmony Plantation site. There are insufficient data to estimate the probability of occurrence of an oil tank farm explosion, although it is probably safe to assume the probability is low. Data exist (such as the multiple explosions and fire occurring in a 90,000 barrel oil storage complex in South Brooklyn on January 3rd and 4th, 1976) but are not compiled and analysed in a form applicable to this scenario.

(3) Constituents, Characteristics, and Fate of Bachaquero Crude Oil and Refined Product

(a) General Considerations. Crude oil is one of the most complex mixtures of chemicals found naturally in the earth. Molecules found in crude oil contain primarily carbon and hydrogen; but oxygen, nitrogen, sulfur, and metals also occur. Empirically, crude oil can be separated into three fractions; these are oil, resins and asphaltenes. The relatively lighter oil fraction can be characterized by defining boiling point ranges of the different molecules that comprise this fraction. For the purposes of discussion here, the relatively heavier resins and asphaltenes together comprise the portion of the crude oil that cannot be removed by distillation, i.e., the residue or residuum. However by using a process of heat and pressure known as cracking, the heavier fractions of petroleum can be broken down into smaller molecules.

The molecules found in all fractions of crude or refined oil can be divided into two principal types, aliphatic or aromatic hydrocarbons. Aliphatic hydrocarbons commonly found in crude and refined oil are paraffins and naphthenes. Paraffins and naphthenes usually comprise the lower boiling fractions of crude oil. The intermediate boiling fractions of crude oil usually have a higher content of aromatics, and the higher boiling and residual fractions of crude oil consist of an even greater content of aromatics, including carcinogenic polynuclear aromatics (PNAs) (Blumer et al., 1971; Kallio, 1976).

The proposed CRDC refinery at Georgetown is designed to process 30,000 BPD (barrels per day) of Bachaquero (Venezuela) crude oil. Two petroleum analyses of Bachaquero crude have been obtained from the U.S. Department of Energy, Bartlesville Energy Technology Center (Tables VII.B-15, and VII.B-16); a third crude petroleum analysis has been obtained from Aalund (1983) (Table VII.B-17). Bachaquero crude is a naphthene base oil characterized by a low API gravity (14.7 to 16.8), high pour point (-10 to 35°F), and high viscosity. It is brownish-black and has a moderately

high sulfur content of 2.4 to 2.68 percent. Naphthene base oils contain few paraffins (compared to paraffin base oils) and the residue of naphthene base oil is high in asphaltenes, or petroleum coke.

TABLE VII.B-15

ASSAY NO. 1 OF BACHAQUERO, VENEZUELA
CRUDE OIL

6-435 b (April 1954)

CRUDE PETROLEUM ANALYSIS

Bureau of Mines Bartlesville Laboratory
Sample 70025

IDENTIFICATION

Bachaquero field

South America
Venezuela

GENERAL CHARACTERISTICS

Gravity, specific, 0.965 Gravity, ° API, 15.1 Pour point, ° F, 35
Sulfur, percent, 2.68 Color, brownish black
Viscosity, Saybolt Universal at 100°F 4,441 sec., at 130°F 1,198 sec Nitrogen, percent, 0.340

DISTILLATION, BUREAU OF MINES ROUTINE METHOD

STAGE 1—Distillation at atmospheric pressure, 744 mm. Hg
First drop, 140 ° F.

Fraction No.	Cut temp. ° F.	Percent	Sum, percent	Sp. gr., 60/60° F.	° API, 60° F.	C. I.	Refractive index, n_D at 20° C.	Specific dispersion	S. U. visc., 100° F.	Cloud test, ° F.
1	122									
2	167									
3	212									
4	257	1.5	1.5	0.729	62.6	-	1.40431	127.3		
5	302	0.9	2.4	.763	54.0	25	1.42215	133.5		
6	347	1.2	3.6	.781	49.7	27	1.43380	133.6		
7	392	1.4	5.0	.812	42.8	35	1.46654	140.2		
8	437	2.2	7.2	.833	38.4	40	1.45784	141.0		
9	482	3.5	10.7	.854	34.2	44	1.46877	145.8		
10	527	4.7	15.4	.873	30.6	49	1.47976	154.6		
STAGE 2—Distillation continued at 40 mm. Hg										
11	392	2.1	17.5	0.901	25.5	58	1.49226	166.9	44	Below 5
12	437	4.9	22.4	.909	24.2	58	1.49902	167.8	55	do.
13	482	5.3	27.7	.921	22.1	60			881	do.
14	527	9.5	37.2	.938	19.4	65			183	do.
15	572	10.2	47.4	.947	17.9	66			455	do.
Residuum		51.6	99.0	1.031	5.7					

Carbon residue, Conradson: Residuum, 11.7 percent; crude, 6.5 percent.

APPROXIMATE SUMMARY

	Percent	Sp. gr.	° API	Viscosity
Light gasoline	-	-	-	
Total gasoline and naphtha	5.0	0.771	52.1	
Kerosine distillate	-	-	-	
Gas oil	13.4	.868	31.5	
Nonviscous lubricating distillate	8.1	.905-.924	24.8-21.6	50-100
Medium lubricating distillate	6.6	.924-.939	21.6-19.3	100-200
Viscous lubricating distillate	14.3	.939-.952	19.3-17.2	Above 200
Residuum	51.6	1.031	5.7	
Distillation loss	1.0			

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Source: U.S. Department of Energy, n.d.

TABLE VII.B-16

ASSAY NO. 2 OF BACHAQUERO, VENEZUELA
CRUDE OIL

Bureau of Mines Bartlesville Laboratory
Sample 57123

IDENTIFICATION

Bachaquero field
Miocene

South America
Venezuela
Zulia

GENERAL CHARACTERISTICS

Gravity, specific, 0.968 Gravity, ° API, 14.7 Pour point, ° F., 20
Sulfur, percent, 2.62 Color, brownish black
Viscosity, Saybolt Universal at 100°F., 3,310 sec.; 130°F., 1,160 sec Nitrogen, percent, 0.370

DISTILLATION, BUREAU OF MINES ROUTINE METHOD

STAGE 1—Distillation at atmospheric pressure, 737 mm. Hg
First drop, 136 ° F.

Fraction No.	Cut temp. ° F.	Percent	Sum. percent	Sp. gr., 60/60° F.	° API, 60° F.	C. I.	Refractive index, n_D at 20° C.	Specific dispersion	S. U. visc., 100° F.	Cloud test, ° F.
1	122									
2	167									
3	212	0.9	0.9	0.779	50.1	-				
4	257	.6	1.5	.782	49.5	42				
5	302	1.1	2.6	.790	47.6	38				
6	347	1.3	3.9	.796	46.3	34				
7	392	1.8	5.7	.823	40.4	41				
8	437	2.5	8.2	.844	36.2	45	1.44282	138.8		
1/ 9	482	3.6	11.8	.861	32.8	48	1.47246	146.6		
10	527									

STAGE 2—Distillation continued at 40 mm. Hg

Fraction No.	Cut temp. ° F.	Percent	Sum. percent	Sp. gr., 60/60° F.	° API, 60° F.	C. I.	Refractive index, n_D at 20° C.	Specific dispersion	S. U. visc., 100° F.	Cloud test, ° F.
11	392	5.7	17.5	0.884	28.6	50	1.48733	-	41	Below 5
12	437	5.6	23.1	.905	24.9	56	1.49936	-	54	do.
13	482	6.2	29.3	.925	21.5	62	1.51027	-	87	20
2/ 14	527	4.1	33.4	.940	19.0	60	1.51916	-	160	44
15	572									
Residuum		65.0	98.4	1.016	7.8					

Carbon residue, Conradson: Residuum, 9.6 percent; crude, 6.5 percent.

APPROXIMATE SUMMARY

	Percent	Sp. gr.	° API	Viscosity
Light gasoline	0.9	0.779	50.1	
Total gasoline and naphtha	5.7	0.799	45.6	
Kerosine distillate	-	-	-	
Gas oil	13.0	.871	31.0	
Nonviscous lubricating distillate	8.5	.899-.929	25.9-20.8	50-100
Medium lubricating distillate	6.2	.929-.960	20.8-15.9	100-200
Viscous lubricating distillate	-	-	-	Above 200
Residuum	65.0	1.016	7.8	
Distillation loss	1.6			

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1/ Distillation discontinued at 482°F.
2/ Distillation discontinued at 509°F.

Source: U.S. Department of Energy, n.d.

TABLE VII.B-17

ASSAY NO. 3 OF BACHAQUERO, VENEZUELA CRUDE OIL

Crude
- °API, gravity: 16.8
- Sulfur, wt%: 2.4
- Viscosity, SSU at 100°F: 1,362
- Pour pt, °F: -10
- Yield, 0° (IVT) to 82°F., vol %: 0.80

Light Naptha
- Distillation range, °F: 82-200
- Yield, vol %: 2.44
- Sulfur, wt %: 0.0075
- Paraffins, wt %: 66.17
- Napthenes, wt %: 31.28
- Aromatics, wt %: 2.55

Heavy Naptha
- Distillation range, °F: 200-300
- Yield, vol %: 3.54
- Sulfur, wt %: 0.026
- Paraffins, wt % 29.38
- Napthenes, wt % 58.96
- Aromatics, wt % 11.66

Naptha
- Distillation range, °F: 300-350
- Yield, vol %: 1.81
- Specific gravity 0.8018
- Sulfur, wt %: 0.1107
- Paraffins, wt % 23.20
- Napthenes, wt % 59.59
- Aromatics, wt % 17.21

Kerosene
- Distillation range, °F: 350-400
- Yield, vol %: 2.11
- Specific gravity 0.8227
- Sulfur, wt %: 0.19
- Paraffins, wt % 25.12
- Napthenes, wt % 54.49
- Aromatics, wt % 20.39

Gas Oil
- Distillation range, °F: 400-500
- Yield, vol %: 6.37
- ° API, gravity: 35.43
- Sulfur, wt %: 0.52
- Aromatics, wt %: 25.29

Gas Oil
- Distillation range, °F: 500-550
- Yield, vol %: 3.93

Gas Oil
- Distillation range, °F: 550-650
- Yield, vol %: 8.95
- Sulfur, wt %: 1.36

Residue
- Distillation range, °F: 650+
- Yield, vol %: 70.24
- °API, gravity: 9.39
- Sulfur, wt %: 3.0
- Nickel/Vanadium, ppm: 74/435

Source: Aalund, 1983

Definition of terms: Tables VII.B-15-17

API Gravity - the measure of gravity of liquid petroleum products on the North American continent, derived from specific gravity according to the following equation:

$$\text{API Gravity} = (141.5/\text{specific gravity}) - 131.5$$

A specific gravity of 1.0 equals an API Gravity of 10.0

Saybolt Second Universal (SSU) - the measure of viscosity of fluids, the time required for the flow of a specific volume of fluid, at three temperatures: 100°F, 130°F, and 210°F.

Cut Temperature - the distillation temperature of a petroleum fraction.

Pour Point - a temperature 5°F above that temperature at which an oil is solid; the lowest temperature at which an oil will flow.

(b) Physical Behavior of Crude Oil. In order to understand the physical behavior of Bachaquero crude when spilled upon the water, it is necessary to define several classes of hydrocarbons based on carbon numbers, since certain size ranges of molecules behave similarly. Molecules in the C_1 to C_4 range, such as methane, ethane, propane and butane, are gases at 20°C. Molecules in the C_5 to C_{10} range, known as light gasoline, gasoline and naphtha, are volatile liquids at 20°C. Molecules in the C_{11} to C_{12} range, such as kerosene, are liquid but less volatile at 20° C. Molecules in the C_{13} to C_{25} range are known as gas oil; light gas oil is used as diesel and furnace fuel and the heavier gas oils are used as industrial fuels. Gas oils are low volatility liquids at 20°C. Molecules with carbon numbers between twenty-five and fifty comprise various grades of lubricants and may be viscous liquids or grease-like solids at 20°C. Molecules with a carbon number greater than fifty can be thought of as residual components (Kolpack and Plutchak, 1976) and are mostly solids held in colloidal suspension in the crude oil at 20°C (Kallio, 1976).

When crude oil is spilled on water the petroleum fractions may undergo the following phenomena (JBF Scientific Corp., 1976) represented diagramatically in Figure VII.B-19:

- The oil will fractionate horizontally, as in the pattern of thick patches surrounded by thinner films, and/or a water-in-oil emulsion may be formed on the surface;
- Some fractions will evaporate;
- Some fractions will sink;
- Some fractions will dissolve in the water; and

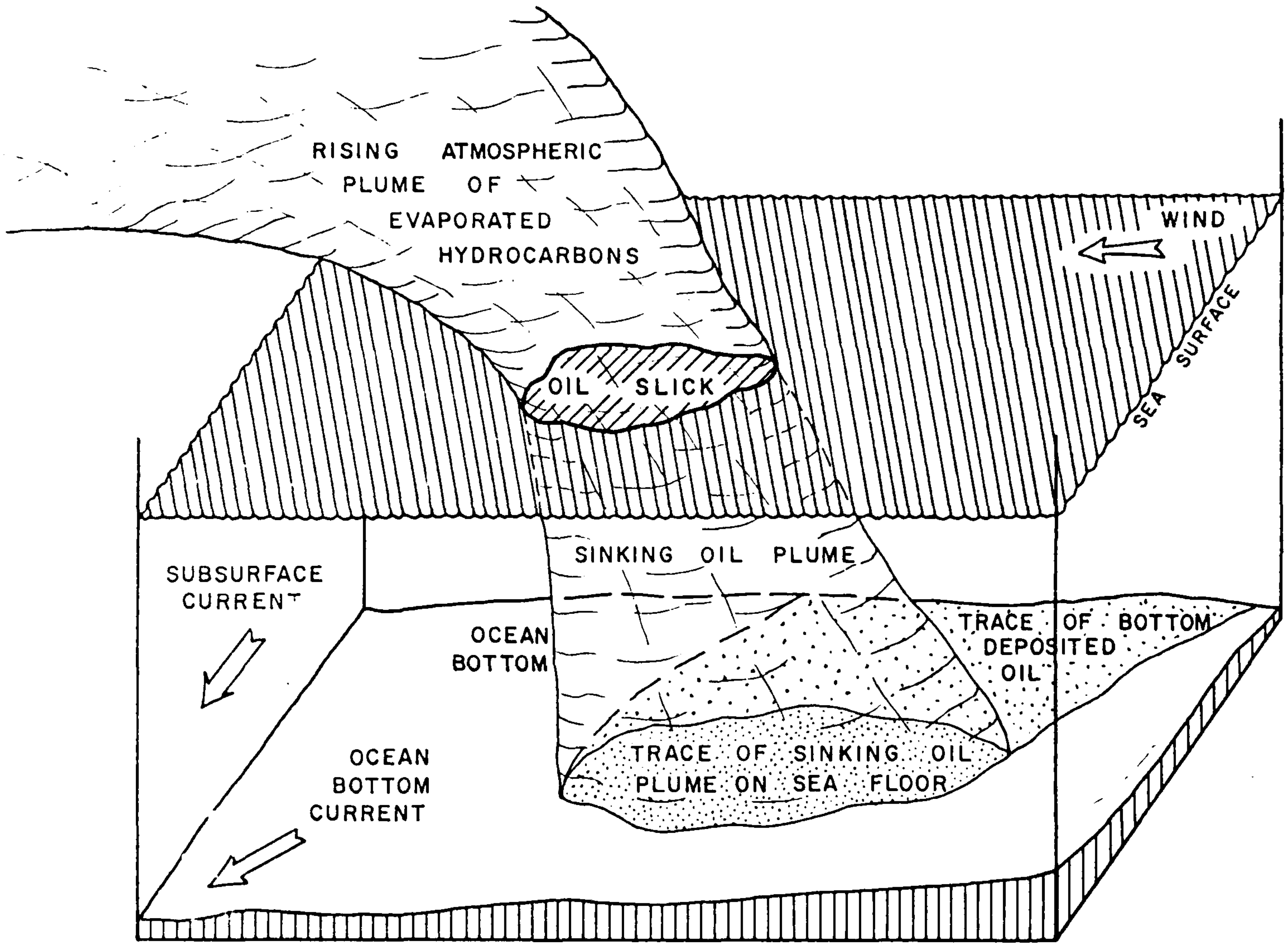

Figure VII.B-19. Block Diagram Showing the Fate of an Oil Slick

Source: Kolpack and Plutchak, 1976

- Some fractions or, in some cases, globules representative of the whole oil composition, may become dispersed in the water.

Evaporation is enhanced by higher temperatures and wind velocities, by horizontal spreading of the slick which increases the surface area of the crude oil, and by mixing of the water column. Molecules with relatively high vapor pressures in the C_1 to C_9 range may be lost within the first few hours of the spill (JBF Scientific Corp., 1976)(Tables VII.B-18 and VII.B-19). Vapor pressures of this fraction range from 275,549.74 mm Hg for methane (C_1) down to 7.16 mm Hg for n-Nonane (C_9). By comparison, the vapor pressure of water is 161,507.60 mm Hg at 372°C and 7.01 mm Hg at 6°C. Chemical analyses of water under crude oil slicks showed that C_1 to C_9 molecules were not detected in water sampled more than twenty minutes after four experimental spills (JBF Scientific Corp., 1976). Hydrocarbons in the C_{10} to C_{12} range in Bachaquero crude will also volatize, but more slowly. However C_{10} to C_{12} molecules do not disappear from the water column without apparent effect. Chemical analyses of sediments and animals several months after oil spills have shown chromatographic evidence of hydrocarbons in the C_{10} to C_{12} range (Blumer et al., 1971). An estimate of the percentage of Bachaquero crude volatilized after a spill can be conservatively based on the combined percentages of C_1 through C_{12} molecules indicated by assays No. 1, No. 2 and No. 3. These percentages are 5.0, 6.6, and 10.7, respectively.

Sinking of crude oil is a function of the density of the crude oil relative to the density of water. Certain sediment transport processes discussd elsewhere in this document will also cause oil to appear in the sediments regardless of the density of the oil; however, the oil being discussed here is heavier than water. The residue fraction of Bachaquero crude makes up a large percentage of the oil and will sink under certain conditions. The three assays of Bachaquero crude are summarized below with respect to specific gravity and percentage residue:

Crude Assay	Percent Residue	Specific Gravity
No. 1	51.6	1.031
No. 2	65.0	1.016
No. 3	70.2	1.004

The specific gravity of seawater varies with temperature and salinity; the lower the temperature and the higher the salinity the greater the specific gravity and vice versa. Thus, at a temperature of 0°C and a salinity of 35.0 o/oo the specific gravity of water is 1.028, whereas at a temperature of 30°C and a salinity of 0.0 o/oo the specific gravity of water is 0.996. If the specific gravity of a crude oil or a crude oil fraction is greater than the specific gravity of water it will sink; if less, it will float. Because the specific gravities of the three assays of Bachaquero crude fall within the range of specific gravities of seawater at different temperatures and salinities, the sinking behavior of each of the three crude assays can be expected to differ. The 70.2% residue fraction of crude No. 1 would sink at all temperatures and salinities experienced in Winyah Bay, its tributary rivers and the coastal environment. The 65.0 % residue fraction of assay No. 2 would sink only at salinities lower than 27 o/oo at 30°C or 20 o/oo at 0°C (Figure VII.B-20). The 51.6 percent residue fraction of assay No. 3 would sink only at salinities of 11 o/oo at 30°C and 5 o/oo at 0°C (Figure VII.B-20). Thus, crude oil with the characteristics of assays No. 2 and No. 3 would tend to float if spilled offshore, but sink if spilled in certain portions of Winyah Bay or its tributaries, depending on the water temperature and the salinity of the receiving water body.

TABLE VII.B-18

APPROXIMATE LIFE AND HALF-LIFE OF SOLUBLE LOW MOLECULAR WEIGHT HYDROCARBONS IN THE SLICKS FROM FOUR CONTROLLED OIL SPILLS

	Approximate Half-Life (Minutes) (50% Remaining)					Approximate Life (Minutes) (None Remaining)				
	C_9	C_8	C_7	C_6	C_5	C_9	C_8	C_7	C_6	C_5
First LaRosa	60	30	<30	<30	a	360 to 1320	420b	60-120	60b	a
Second LaRosa	<30	<30	<30	a	a	270b	270b	<120	a	a
First Murban	90	50	30	a	a	120 to 270	180b	120b	a	a
Second Murban	90	30	20	<30	<30	360b	300b	100	<60	<30

[a]None found even in earliest samples

[b]Approximate number found

SOURCE: JFB Scientific Corp., 1976

TABLE VII.B-19

VAPOR PRESSURES OF REPRESENTATIVE ALIPHATIC HYDROCARBONS COMMONLY FOUND IN CRUDE OIL

Formula	Name	Vapor Pressure[1] (mmHg)
CH_4	Methane	275,549.74
C_3H_8	Propane	6,666.7075
C_5H_{12}	n- Pentane	372.87108
C_7H_{16}	n- Heptane	39.810002
C_9H_{20}	n- Nonane	7.163080
$C_{10}H_{20}$	n- Decane	1.2901556
$C_{11}H_{24}$	Undecane	0.4806788
$C_{12}H_{26}$	n- Dodecane	0.3323262
$C_{13}H_{28}$	Tridecane	.00636328
$C_{15}H_{32}$	Pentadecane	.0080835
$C_{18}H_{38}$	Octadecane	.0012604
$C_{25}H_{52}$	Pentacosane	.00000216
$C_{29}H_{60}$	Nonacosane	.0000000015

[1]at 20°C

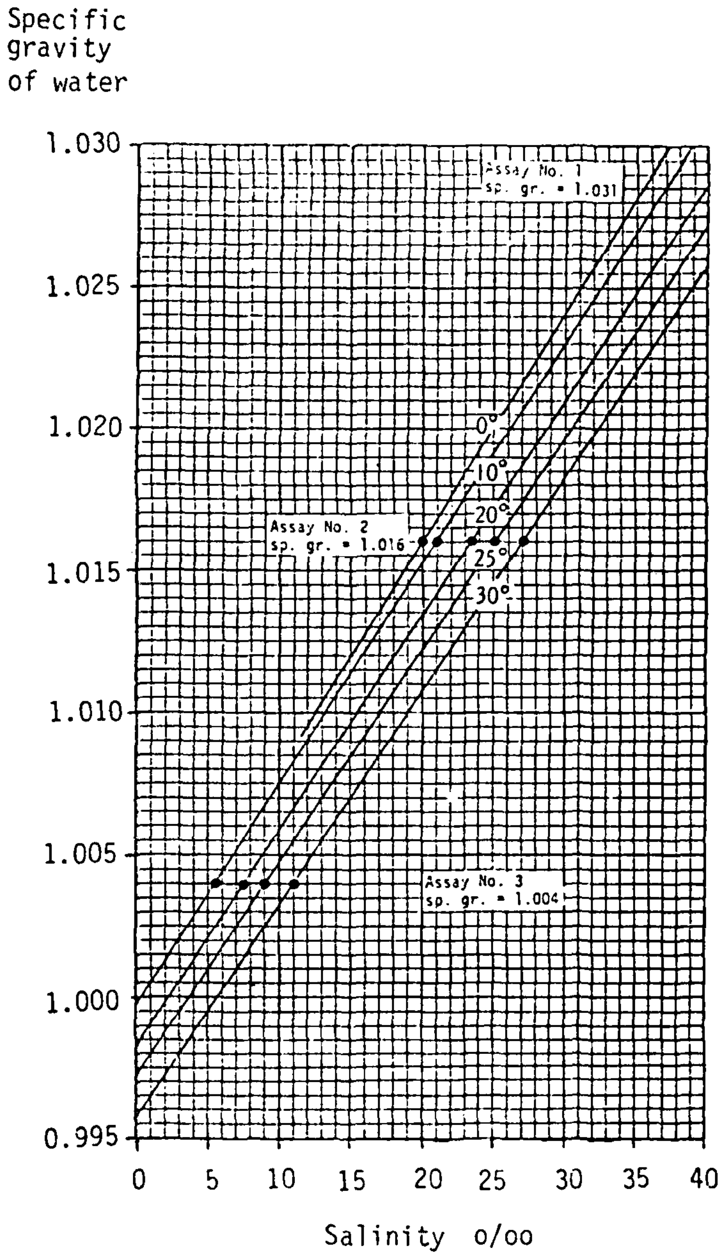

Figure VII.B-20. Relationship between temperature and salinitv of water and sinking of Bachaquero crude oil, (Harvey, 1969).

(c) Chemical Constituents and Behavior of Crude Oil. Paraffins comprise about 35 percent of the non-residual oil fraction in Bachaquero crude, or 10 to 15 percent of the total oil fraction. In typical oils the paraffin content is about 20 percent; the normal paraffins in crude oil range from C_1 to about C_{40}, although there are wide variations among different crudes (Kallio, 1976). The paraffins, in general, are nontoxic and will be degraded in aerobic environments by microbial action.

Naphthenes comprise about 50 percent of the non-residual fraction of Bachaquero crude, or 15 to 25 percent of the total oil fraction. Naphthenes are known to be subject to considerable microbial degradation and, although more toxic than the paraffins, are not characterized by the high toxicities of the aromatics.

Aromatics comprise about 15 percent of the non-residual fraction of Bachaquero crude, or 5 to 10 percent of the total oil fraction. Aromatics generally do not account for more than 20 percent of the oil fraction in crude oil (Kallio, 1976). Polynuclear aromatic compounds with nine rings have been identified in crude oil but this does not represent a maximum size.

The residual fraction of Bachaquero crude makes up approximately 50 to 70 percent of the total oil fraction of the crude. Also known as asphalt or petroleum coke, the residue is composed of non-volatile solids with polycyclic structures (Morrison and Boyd, 1974). Kallio (1976) describes asphaltenes as high molecular weight materials held in colloidal suspension in the oil; usually they make up from 0 to 20 percent of the total crude. The following quotation (with parenthetical comments added) from Kallio (1976) is pertinent here: "Molecular weights for asphaltenes have never been accurately determined, presumably because of the peculiar nature of their solubility characteritics. Molecular weights from 500 to 100,000 have been claimed; the commonly quoted value of 10,000 seems more reasonable. More sulfur, nitrogen, and oxygen occur in the asphaltene fraction than in resins or oils. In addition, organically complexed nickel and vanadium (74 ppm and 435 ppm, respectively, in Bachaquero crude) occurs in the asphaltene molecules. Resins are not well characterized but are known to be highly aromatic, probably contain materials which might simplistically be called junior asphaltenes--most likely very large polynuclear aromatic hydrocarbons are included."

The chemical behavior of the various fractions of crude oil is related to the individual molecule's attraction to water, called polarity. Different polar molecules move into the water phase at different rates. Polar molecules have been found to be dissolved as quickly as three to six hours after a spill, with all of the soluble compounds in the spill reaching equilibrium in 20 hours (Parker et al., 1976). Unlike non-polar molecules, dissolved polar molecules are not available for evaporation. Winters and Parker (1977) found that less polar compounds such as alkyl benzenes, indans and naphthalenes were rapidly lost from solution, with negligible concentrations remaining after 24 hours. More polar compounds such as alkyl phenols, anilines, and indoles were generally present at greater than 50 percent of their initial concentrations after five days.

The occurrence and solubility of paraffins and aromatics in water after experimental spills involving fresh and weathered crude oil has been established by Bieri et al. (1981), Winters and Parker (1977), and USEPA (1980). Tables VII.B-20 and VII.B-21 indicate the concentrations and persistence of many aliphatic aromatic compounds from five to 289 days after an experimental South Louisiana crude oil spill. Similar data are unavailable for Bachaquero crude; however, many of the constituents are common to both South Louisiana and Bachaquero crude. Persistence of these compounds and weathering effects are expected to be similar.

Table VII.B-20. CONCENTRATION OF n-PARAFFINS IN WATER EXPOSED TO EXPERIMENTAL SPILLS OF SOUTH LOUISIANA CRUDE OIL (IN PPB)

No. of Carbons in n-paraffin	Fresh Crude Spill				Weathered Crude Spill		
	+6h 155	+31h 156	+76h 158	+216h 161	+6h 158	+45h 159	+120h 160
15	n.d.	0.50	2.15	n.d.	1.35	0.29	0.34
16	n.d.	0.84	4.02	0.11	2.22	0.64	0.84
17	n.d.	1.53	5.04	0.21	2.96	1.11	1.39
19	n.d.	2.07	6.35	0.40	3.94	1.45	1.63
20	n.d.	2.33	6.63	0.51	4.68	1.62	1.70
21	n.d.	2.49	6.80	0.65	5.37	1.87	1.78
22	n.d.	2.49	6.57	0.70	5.37	1.83	1.78
23	n.d.	2.11	5.44	0.63	4.85	1.64	1.58
24	n.d.	1.76	4.65	0.57	4.19	1.43	1.46
25	n.d.	1.40	3.40	0.51	3.33	1.14	1.16

n.d. Homologuous series of even n-1- alkenes present only.

Source: Bieri et al., 1981

Table VII.B-21. TIME DEPENDENCE OF AROMATIC HYDROCARBON CONCENTRATIONS (PPB) IN WATER AFTER EXPERIMENTAL SPILLS OF SOUTH LOUISIANA CRUDE OIL

	Fresh Crude Spill				Weathered Crude Spill		
Time after Spill (hrs)	+6h	+31h	+76h	+216h	+6	+45h	+120h
Sample Number	155	156	158	161	158	159	160
Compounds							
Naphthalene	n.d.	1.80	n.d.	n.d.	1.13	n.d.	n.d.
2-Methylnaphthalene	n.d.	1.05	0.18	n.d.	0.96	n.d.	n.d.
1-Methylnaphthalene	n.d.	1.04	0.20	n.d.	1.04	0.35	0.31
Biphenyl +2,6-Dimethylnaphthalene*	n.d.	0.50	0.19	n.d.	0.65	0.17	0.35
1, 3-Dimethylnaphthalene*	n.d.	0.71	0.31	n.d.	1.02	0.29	0.57
1, 5-Dimethylnaphthalene*	n.d.	0.29	0.09	n.d.	0.47	0.13	0.25
2, 3-Dimethylnaphthalene*	n.d.	0.10	0.07	n.d.	0.15	0.05	0.07
3-Methylbiphenyl+C_3-Naphthalene+ 4-Methylbiphenyl	n.d.	0.19	0.15	n.d.	0.37	0.11	0.26
C_3-Naphthalene	n.d.	0.18	0.16	n.d.	0.33	0.13	0.21
Methylbiphenyl+C_3-Naphthalene	n.d.	0.13	0.11	n.d.	0.41	0.11	0.17
2,3,5-Trimethylnaphthalene	n.d.	0.13	0.11	n.d.	0.26	0.10	0.16
C_3-Naphthalene+C_2-Biphenyl	n.d.	0.09	0.08	n.d.	0.16	0.05	0.12
Fluorene+C_4-Naphthalenes+ C_2-Biphenyl+C_5-Naphthalene	n.d.	0.17	0.15	n.d.	0.31	0.11	0.22
C_4-Naphthalene+C_2-Biphenyl+ C_3-Biphenyl	n.d.	0.08	0.07	n.d.	0.15	0.07	0.12
Methylfluorene+C_4-Naphthalene+ C_3-Biphenyl+	n.d.	0.20	0.28	n.d.	0.31	0.15	0.20

* Other isomers of C_2-naphthalene may be superimposed

n.d. Peak not detectable

Source: Bieri et al., 1981

Asphaltenes can be expected to be incorporated into the sediments within a short time in the area impacted by a spill of Bachaquero crude. Since these high molecular weight compounds make up the largest portion of the total crude, their presence and expected persistence in bottom sediments would constitute a major, if not primary, concern relevant to both water quality and ecological effects of an oil spill. Transfer of emulsified crude oil from the water column to the sediments has been observed to occur within 96 hours of an experimental spill of Empire Mix crude oil (USEPA, 1980)(Table VII.B-22).

Persistence of the various fractions of crude oil varies; n-pariffins are less persistent than naphthenes, and these in turn are less persistent than the aromatics. The C_{13} to C_{17} fraction of crude oil is said to have an environmental persistence of eight months or more (with toxicity much of this time), similar to #2 fuel oil studied in an actual spill near Woods Hole Oceanographic Institution in Massachusetts (Blumer et al., 1971). Blumer and Sass (1972) found that "Branched and cyclic hydrocarbons are attacked even more slowly than the n-alkanes [n-paraffins]; after two years, isoprenoids and alicyclic [naphthenes] and aromatic hydrocarbons remained prominent in the polluted sediments." Blumer et al. (1971) concluded that "Crude oil and oil products are persistent poisons, resembling in their longevity DDT, PCB and other synthetic materials. Like other long-lasting poisons that, in some properties, resemble the natural fats of the organisms, hydrocarbons from oil spills enter the marine food chain and are concentrated in the fatty parts of the organisms. They can then be passed from prey to predator where they may become a hazard to marine life and even to man himself." Asphaltenes are known to contain carcinogenic polynuclear aromatic compounds (PNAs). Of major concern is the probability that these toxic substances, once introduced into the Winyah Bay or North Inlet ecosystems, would persist in the sediments and be remobilized whenever wind and wave action combine to resuspend sediments (likely to be a frequent occurrence in such a wide shallow estuary as Winyah Bay), thus acting as a continuous source of contamination until exhausted years later.

(d) Physical Behavior of Refined Product. The product slate of the proposed refinery includes the following hydrocarbon fractions:

Fraction	Carbon No.
Fuel Gas	C_3 or less
Butanes	C_4
Poly Gasoline	C_5 to C_{10}
JP4	C_{11} to C_{12}
Diesel	C_{13} to C_{17}
Gas Oil	C_{18} to C_{25}
Coke	C_{50} or more

Spills of fuel gas and butanes would not affect the aquatic environment since these substances are gases at environmental temperatures. A spill of poly gasoline would evaporate quickly but would leave behind traces of polar naphthenes and aromatics in the water column and to a lesser extent in the sediments. A spill of JP4 (the most likely product to be transported by barge through Winyah Bay) would evaporate less quickly, and would behave much the same as the kerosine fraction of a crude oil spill. Spills of diesel fuel and gas oil would not evaporate very quickly but would behave much the same as a spill of a light crude oil such as Arabian Crude. Spills of JP4, diesel and gas oil would find their way into the water column and the sediments. All of the foregoing refined product spills would float in all salinities and in freshwater. A spill of coke would be much like a spill of the asphaltene fraction of crude oil. The coke would sink and become incorporated into the sediments.

TABLE VII.B-22

CONCENTRATIONS IN ppb (dry weight) OF AROMATIC COMPOUNDS
IN UNCONSOLIDATED SEDIMENT FROM THE FRESH SLAC OIL SPILL

Time after spill (hrs.)	Prespill	+6	+31	+76	+216	+1370	+4150	+6938
Sample Number	154	155	156	158	161	168	191	195
Compounds								
Naphthalene	--	4999	166	--	104	119	92	--
2-Methylnaphthalene	--	2270	104	--	66	170	54	--
1-Methylnaphthalene	--		62	--	28	93	23	--
C_2-Naphthalenes	--	1874	228	--	208	425	191	--
C_3-Naphthalenes	--	242	93	35	104	<405	239	--
C_3 & C_4-Naphthalenes	--	83	41	10	38	136	107	--
C_4-Naphthalenes	--	--	--	--	--	--	--	--
C_5-Naphthalenes	--	--	<83	<49	<159	<644	<399	19
Biphenyl	--	437	643	--	609	543	629	187
Acenaphthene	--	187	41	8	33	127	69	--
Methylbiphenyls	--	83	83	5	55	255	130	--
C_2-Biphenyls	--	21	21	10	16	<102	107	--
C_3-Biphenyls	--	--	--	--	--	--	--	--
Dibenzofuran	--	104	42	10	38	153	77	--
Methyldibenzofuran	--	--	21	33	16	<85	54	--
Fluorene	--	<83	62	<20	<82	<254	<77	--
Methylfluorene	--	--	--	--	--	--	--	--
C_2-Fluorenes	--	--	21	29	<82	<245	138	19
Phenanthrene	--	90	249	<147	433	611	383	75
Methylphenanthrene	--	--	685	<284	1046	1272	<659	<169
C_2-Phenanthrenes	--	--	<187	<103	<197	<237	261	94
C_3-Phenanthrenes	--	--	--	137	--	--	--	--
Dibenzothiophene	--	--	31	20	55	54	31	19
Fluoranthene	--	<38	<435	<245	<241	<271	<368	<712
Σ, Sum of total above	--	12281	3298	1145	3610	6201	4088	1294
UCM (ppb)	--	--	55000	41000	69000	202000	191000	459000
Chlorinated HCs	--	--	1679	638	4133	2604	688	562
Σ/UCM	--	--	0.06	0.03	0.05	0.03	0.02	0.003

(e) Chemical Constituents and Behavior of Refined Product. Refined product will contain the paraffins, naphthenes and aromatic present in the crude oil plus the products of the cracking process. Refined product spills would not contain the higher molecular weight PNAS and asphaltene molecules, however refined products may contain high proportions of both polar and non-polar aromatic molecules (Table VIII. B-23) making these fractions highly toxic to aquatic life (Blumer, 1972). Refined product spills would be somewhat less persistent than crude oil spills in Winyah Bay, but could, nevertheless persist for months or years (Blumer, 1971). Degradation of refined product spills would proceed more rapidly than degradation of crude oil at the rates of similar fractions in crude oil.

(4) Impacts to Sediments and Sediment Transport

(a) Spill Scenarios. Seventeen cases are presented for spill scenarios that range in volume from 6.5 barrels to 140,000 barrels (Table VII.B-13). The discussions of these cases are qualitative, rather than quantitative, in nature. Quantitative predictions have not been made because of the lack of data on sediment transport in the study area, as discussed earlier on page VI.C-22, and because of seasonal variations in bottom sediment distribution. Furthermore, the physicochemical interactions between oil and sediments in estuarine environments are not well understood. Nevertheless general characterizations are possible and have been presented.

Catastrophic oil spills represent total cargo losses of 140,000 barrels into Winyah Bay. They have been presented under worst case scenarios. It is important to understand that this represents a worst case for the total environment, but not necessarily a worst case for sediments. Nevertheless impacts on the sedimentary environment would be significant. For comparative purposes, a brief summary of the Amoco Cadiz oil tanker spill off the coast of Brittany, France in 1978 is presented (Hann et al. 1978). The tanker released approximately 199,716 metric tons (220,000 tons) of crude oil off the Brittany coast. It was estimated that 72,624 metric tons (80,000 tons; ± 50 percent) went ashore. Approximately 63,546 metric tons (70,000 tons) were estimated to have evaporated and 81,702 metric tons (90,000 tons) were unaccounted for. It was assumed that some portion of the oil was photochemically and biologically degraded, but that a large quantity remained in the water column and was transported down current or entered the bottom sediments.

There are several major differences between the Amoco Cadiz spill and a potential spill in Winyah Bay. These include differences in the chemical makeup of Arabian Gulf vs. Venezuelan crude oil, meteorological conditions, hydrology and offshore vs. estuarine environment, to list a few variables. The primary difference which makes a spill in Winyah Bay potentially worse is the enclosed nature of the estuary. That is to say, the oil will not leave the bay in large quantities by simply being transported "down current," because it is not an offshore incident. As a result, under a worst case scenario a region of limited extent, such as Winyah Bay and its vicinity, will bear the full brunt of the spill. Variations will be presented under several cases.

TABLE VII.B-23

IDENTIFICATION AND CONCENTRATION (mg/l) OF MAJOR COMPONENTS IN THE WATER SOLUBLE FRACTIONS OF FOUR FUEL OILS

Major Components	Montana	Baytown	New Jersey	Baton Rouge	API
1,2,4 Trimethyl Benzene	.37	.56	.42	.50	.22
C_3-Benzene[1]	.23	.23	.21	.29	.16
Indan + C_4-Benzene	.22	.26	.13	.11	.18
Methylindan	.25	.15	.13	.07	.25
Naphthalene	.64	.75	.66	.39	.87
o-Toluidine	.37	.34	.12	.04	.14[2]
p-Toluidine	.14	--	.02	--	--
m-Touidine + 2,6 Dimethylaniline	.53	.24	--	--	--
1-Methylnaphthalene	--	--	--	--	.36
2-Methylnaphthalene	.33	.51	.84	.48	.51
2,4 Dimethylaniline	.24	--	--	--	--
1-Methylnaphthalene	.20	.30	.46	.28	--
2,5 Dimethylaniline	.30	.04	.03	--	--
2,6 Dimethylphenol + C_2-Aniline	.19	.13	--	.04	.10[2]
3,5 Dimethylaniline + dimethylnaphthalenes	.33	--	--	--	.35
2,3 Dimethylaniline + Dimethylnaphthalene + C_3-Aniline	.26	.07	.08	.04	--
Dimethylnaphthalene + 3,4 Dimethylaniline + C_3-Aniline	.32	.08	.16	.08	.07
o-Cresol + 2,4,6 Trimethylphenol + dimethylnaphthalene	.42	1.16	.46	.25	.54
2,6 Dimethylnaphthalene	.14	.11	.12	.05	--
m + p Cresol + 2,4 + 2,5 Dimethylphenol	.96	1.95	.60	.32	1.33
2,3 Dimethylphenol + C_3-Phenol	.18	.12	.14	.08	.46
3,5 Dimethylphenol + C_3-Phenol	.51	.60	.45	.24	.63
3,4 Dimethylphenol + 2,3,5 Trimethylphenol	.06	.15	.21	.13	.39
C_3-Phenol	.09	.06	.10	.02	.05
Indole + Methylindole	.24	.03	.07	--	.12
Methylindole + Dimethylindole	.35	.02	.11	.06	.07
Methylindole + Dimethylindole	.15	.02	.08	--	--
Dimethylindole + C_3-Indole	.05	.02	.06	.05	--
Perinaphthenone	--	--	--	--	.20
Total Organics by G.C.	12.8	12.9	10.5	7.0	--
Total Identified Organics	8.07	7.90	5.66	3.52	7.63
Methylnaphthalenes	.53	.81	1.30	.76	.87
Dimethylnaphthalenes	.31	.24	.55	.41	.33
Phenols	2.33	4.12	1.96	1.08	3.54
Anilines	2.57	.72	.27	<.02	.19
Total Organics by weight	16	19	14	9	15

[1] Notation C_2, C_3 or C_4 indicates parent compound plus 2, 3 or 4 additional saturated carbon atoms in side chains of unspecified chain length.

[2] The API oil contains benzothiophene in the o-Toluidine peak; 2,6 dimethylphenol peak contains some methylbenzothiophene.

Source: Parker et al., 1976

In Case 1, 667 barrels of refined product are spilled during the summer as a result of a barge collision with the pilings of the Harrell Siau Bridge in the Intracoastal Waterway. This spill would occur during a period of low river flows and during flood tide. Under this scenario, the wind is approximately 215° from the north, allowing the spilled jet fuel to travel upriver. Some evaporation of the spill would occur but this would not remove a major percentage of the volume. Interaction with suspended particles would be expected, particularly with the aliphatic portions of the fuel. Portions of this fuel would be incorporated in the sediments of the Waccamaw River and upper Winyah Bay. Persistence in the sediments could be eight months or more with toxicity existing much of this time, as was discussed previously for the C_{13} to C_{17} fraction of crude oil.

In Case 2, 112 barrels of oil and 112 barrels of jet fuel are spilled in early spring as a result of pipeline ruptures during a period of high river flow and at slack high tide. Both the suspended load and bed load would be higher than under average conditions. Under these high freshwater flow conditions, however, most of the oil would not settle to the bottom at the spill site but would be carried to the south shore of the Sampit River and into the upper harbor area near the Port Authority piers. As the oil and jet fuel carried downstream, the mechanical energy would decrease and the salinity would increase, allowing for flocculation of spilled material and suspended solids. In early spring, microbial decomposition is near minimum in the water column and on the bottom surface. A portion of the spilled oil and jet fuel would reach Winyah Bay. The majority of the spill that settles to the bottom probably would be buried by sediment transported into the bay by the Waccamaw and Pee Dee Rivers. The jet fuel would be expected to evaporate to some extent, but a greater portion of this toxic contaminant would remain and could adversely impact the biota in the spill area.

In Case 3, 9.5 barrels of oil are spilled at Pier 31 in late spring during a period of average flow in the Sampit River. Between 1978 and 1981, the average salinities at this location varied from 0.8 to 7.0 parts per thousand (ppt). At these low salinities, some flocculation of either oil or clay particles would be expected, particularly at the higher limits. In brackish water (10 ppt), oil alone can agglomerate to form a surface slick, but oil with clay can rapidly form large flocs that eventually settle to the bottom. Due to the volume of streamflow, salinity levels, and the occurrence of suspended particulates in the river, it is likely that slicks, direct dissolution and flocculation would occur. Some oil also would be evaporated, emulsified, dispersed, and oxidized. Emulsification would increase significantly the area that would be affected. These processes would account for most oil removal or dispersal. Some of the oil settling to the sediments would be removed by dredging operations as well as by biodegradation, which would be high at this season. At this time of year, biodgradation would occur both in the water column and on the bottom surface.

In Case 4, 6.5 barrels of jet fuel are spilled from a barge at Pier 31 during handling and transfer operations. This occurs in January on an outgoing tide when winds are from the west and river flow conditions are moderately high. The fuel oil will be flushed from the Sampit River within two hours and probably make landfall on Rabbit and Hare Islands. Interaction with suspended particles could cause deposition of this oil anywhere along the expected spill track shown in Figure VII.B-6. Much of the remaining spill probably would become incorporated into the shoreline sediments of the islands. Fuel oil incorporated into bottom or shoreline sediments could be expected to persist for many months and be toxic for much of that time. The small volume of the spill, however, would probably not create any major impacts to sediment transport.

In Case 5, 1,217 barrels of oil are spilled at Pier 31 in early spring. The spill would occur under fresh or brackish water conditions; thus flocculation of oil to the bottom would be less at the spill site than at more saline locations. It is anticipated that wind and flood tidal currents would move the spill toward the west, up the Sampit River. Given the high river flow at this time of year the salinity would be low and could decrease flocculation rates of oil in the river. Oil would collect in the bends of the river, become grounded and penetrate into the shoreline sediments, where it could persist for years. As the tide changes, the portion of the spill that is not bound up in river shoreline sediments would be carried out into upper Winyah Bay, where the salinity is higher. It would be carried into the bay with sediment-laden river water (high spring river flows). As a result, oil and clay could form flocs and settle to the bottom. Some oil could be incorporated into bottom sediments as a result of direct dissolution. A portion of the lighter fraction would evaporate or emulsify, thus increasing the area of impact. Microbial decomposition would be minimal at this season, so oil settling to the bottom sediments would not be degraded significantly by this process. As a result, the settled flocs would be subject to burial by new sediments transported into the bay by high river flows.

In Case 6, a major spill of 42,000 barrels of crude oil occurs at Pier 31 on the Sampit River during mid-ebb tide under moderate river flow conditions. The combination of river flow, wind direction and ebbing tide would force much of the spill towards Winyah Bay. As the tide continues to fall, both shores of the Sampit River east of Pier 31, the southerly portion of Georgetown Harbor, Sampit Point, and Rabbit and Hare Islands would be fouled before the tide changes. Where these shorelines are marshy, the oil would penetrate the sediments and persist. Shoreline stranding could be a major sink for the oil. As the tide changes and the crude oil moves along the western shore of Waccamaw Neck into the Waccamaw River, major impacts could occur. In fact, impacts to the riverine system could be greatest under this spill case. The Waccamaw River serves as a portion of the Intracoastal Waterway. As a result, its main channel is six to nine m (20 to 30 ft) in depth. If tidal and streamflow mixing is weak in the Waccamaw River channel, a saltwater wedge could intrude up the river below the freshwater output. Depending on the salinity and availability of fine-grained particulates, oil and particulates could form flocs and precipitate to the bottom. Depending on the magnitude of flocculation in the lower reaches of the river, this spill could adversely affect sediment transport processes in the river. At this time of the year (July) microbial degradation is at a maximum. This process, along with evaporation, emulsification and oxidation, would remove a portion of the spill volume, although emulsification could increase the area of impact.

In Case 7, 2,277 barrels of oil are spilled near the mouth of the Sampit River in the fall. This would occur under average flow conditions at slack high tide, moving the spilled oil downstream from upper Winyah Bay. Given the prevailing winds from the northeast, the spill would travel along the western shore of the bay where the lighter fractions of the spilled oil would be deposited on tidal flats and marshes. The higher salinities in upper Winyah Bay would cause oil and clay to form flocs and settle to the bottom. Oil incorporation into bottom sediments also could take place by direct dissolution. As shown previously in Table VI.C-13 and Figure VI.C-4, the percentage composition of sediments in upper Winyah Bay has varied considerably over time. This leads to the possibilities that the settled oil could be either buried by new sediments under conditions of average or low flows and tides or, conversely, could be transported elsewhere in the bay by turbulent or high flow conditions. Depending upon the time of travel from the spill site, portions of the oil slick would evaporate, emulsify, disperse or oxidize. During the fall, biodegradation rates would be decreasing after reaching a summer

maximum. This would increase the persistence of oil in the water column and on the bottom surface.

In Case 8, 17,000 barrels of refined product are spilled near the mouth of the Sampit River in October. This would occur under low river flow conditions during slack low tide with winds from the southwest. This is anticipated to result in the movement of the spilled aviation fuel into and up the Pee Dee River. Although some evaporation would occur, this large spill would cause extensive amounts of fuel oil to be incorporated into the sediments at the mouth of the Sampit River, and perhaps further upstream, in the lower Pee Dee River and portions of upper Winyah Bay. Some of this toxic material could enter the abandoned rice fields along the Pee Dee river and interact with the resident flora and marsh sediments. The impacts to sediments are expected to be persistent and the impacts to biota could be severe. Discussions of effects on biota appear in the fish and wildlife resources portion of the EIS.

In Case 9, 140,000 barrels of crude oil and 17,000 barrels of refined product are spilled at the convergence of the Western Channel and Winyah Bay Channel during slack low tide under conditions of low flow in the Sampit, Pee Dee and Waccamaw Rivers. This would occur with 41 knot (47 mph) gale-force winds from the southwest. With the conditions presented above, a rising tide would move spilled oil and refined product not only into the upper bay but also up the Sampit, Pee Dee and Waccamaw Rivers. Additionally, before the tide change the slick would cover both the eastern and western shoreline of Winyah Bay above Frazier Point and would foul portions of Rabbit and Hare Islands. After the tide changes and the spill moves down the bay, it is likely to foul Belle Isle Gardens, Esterville Plantation, the Intracoastal Waterway, the western shore of Marsh Islands, Cat Island, and North and South Islands. These areas are largely marsh areas and tidal flats. The spilled material may undergo rapid penetration and persist for years. As indicated elsewhere in this document, the freshwater/saltwater interface would reach Pennyroyal Creek on the Sampit River and would reach Mile 16 in both the Pee Dee and Waccamaw Rivers under low streamflow and high tide conditions. It is assumed that these saline waters would carry along both fine-grained sediments and a significant volume of oil and refined product. Oil and clays would form flocs that would precipitate to the bottom of the rivers and the upper bay. Precipitation of the flocs would probably be enhanced by water turbulence in the bay. The alaphatic component of the jet fuel would interact with suspended sediments and sink, albeit to an unknown degree. The volatile components would be prone to rapid evaporation; however, thick spills that include crude oil may form a crust that traps volatile toxics in the water column underneath until mechanical forces such as wave action break the crust and restart the evaporation cycle (Murray, 1982). The probable magnitude of this event would alter sediment transport mechanisms in the affected area, because the newly formed flocs would not behave in the same manner as uncontaminated sediments. For example, the finer-grained material would no longer be available to form suspended sediment loads. As streamflows increased to more average flows, newly introduced sediments from upstream could bury the contaminated sediments. Alternatively, high streamflows could cause scouring of the affected stream bottoms and carry contaminated material either downstream or into Winyah Bay.

Although the upper bay and rivers are predicted to be the areas of primary impact, the shorelines and other areas of the bay indicated above would receive lesser amounts of the heavier fractions of oil as a result of tidal changes, shifts in wind direction, and the eventual resurgence of sediment transport from increased river flow. During this period of the year (June), microbial decomposition, which is at a maximum, would degrade a portion of the spilled oil in the water column and

at the bottom surface, although the toxic refined product may decrease microbial activity by an unknown degree.

Under Case 10, 1,700 barrels of refined product are spilled in the Intracoastal Waterway, midway between the western channel and Minim Creek at slack high tide with no winds. As the tide ebbs, the spilled aviation fuel would be carried into Minim Creek, Big Duck Creek, the North Santee River and North Santee Bay. Some of the spill would be lost through evaporation. However, much of the spill would interact with suspended particles and settle or penetrate into the bottom sediments. There also would be fouling of the shorelines as the tide receded. Oil incorporated into the sediments would be persistant and toxic for many months.

In Case 11, 14,000 barrels of crude oil are spilled near the north end of Range D of the Winyah Bay channel during slack low tide with winds from the northeast. The flood tide would carry a portion of the spill along the northern shore of Cat Island. Fouling of the shoreline would occur along with penetration of oil into the sediments. The shoreline fouling in this marshy area could be significant. During this time there would be some evaporation and emulsification of the oil. There also would be flocculation of a portion of the oil and subsequent settling to the bay bottom in the high salinity waters of the lower bay during flood tide. A portion of the oil also could be incorporated into bottom sediments (particularly muds) by direct dissolution. During this time of the year (April), microbial degradation is not at a maximum. Consequently this would have only a minor effect on spill removal.

During the next several tidal cycles, a portion of the spill would remain in the vicinity of the lower bay and another portion would enter the Intracoastal Waterway and creeks. A minor portion of the oil remaining in the bay would be expected to foul the shorelines of Cat Island and much of the lighter fraction of crude oil in the bay would be expected to evaporate or emulsify within the first several days of the spill. Emulsification would increase the area of impact to an unknown degree. For the heavier fractions of crude oil, the salinity of the bay in the spill area would be sufficiently high during flood tides for oil alone to flocculate and settle to the bottom. During ebb tides when salinities would be lower, available clay particles exist near the shorelines that could adsorb oil and flocculate to the bottom. Direct dissolution of oil also would result in oil incorporation into bottom sediments.

An undetermined volume of spilled crude oil would enter the Intracoastal Waterway and ultimately reach Minim Creek, Big Duck Creek, the North Santee River and North Santee Bay, as well as Mosquito Creek on eastern Cat Island. The surface slicks would foul the shorelines along the lengths of the creeks and waterway, and where the shores are marshy, the oil would penetrate the sediments and could persist for years. Where exposed compacted tidal flats predominate, most of the oil would not adhere to or penetrate the compacted sediments (Gundlach and Hayes, 1978). The lighter fraction of oil entering the high salinity environment of North Santee Bay would continue to evaporate and the heavier fraction would flocculate either alone or in combination with clay particles and settle to the bottom. By the time the remaining oil entered the North Santee River and North Santee Bay, however, most of the spill would have evaporated or become bound in shoreline or bottom sediments elsewhere. Consequently only minor or insignificant impacts to sediment transport would be expected. Sediments transported by the North Santee River from upstream of the impacted area more likely would bury the deposited oil.

In Case 12, 140,000 barrels of oil are spilled in the Winyah Bay Channel, 0.4 km (0.25 mi) south of North Island during slack low tide under conditions of average flow in the Pee Dee, Waccamaw and Sampit Rivers. This would occur with 8.6 knot (10 mph) winds from the southwest. Given the level of streamflows of the rivers and the rising tide during the spill event, the greatest percentage of the oil would be directed towards Mud Bay, Marsh Islands, Pumpkinseed Island and North Island. Additionally, Cottonpatch Creek and adjacent creeks on North Island will receive impacts. Saline conditions would allow for flocculation of oil alone, as well as flocs composed of oil and clay. The resulting precipitation of the flocs would probably blanket the bottom of Mud Bay. The marshy shorelines also would receive quantities of oil that would penetrate the surface and persist for years. This also could occur in the North Island creeks and marshes to a potentially significant but unknown degree. The low energy environment of Mud Bay, as characterized by its bottom sediments, depth and distance from the main channel, indicate that Mud Bay serves as a sediment sink rather than as a sediment source. It would appear, therefore, that oil settled on the bottom would persist for years, especially as additional sediment influxes buried the contaminated particles and precluded aerobic biodegradation. Nevertheless buried material could be reintroduced to the water column if a major storm stirred up the bottom sediments. During the first days of a spill event, a portion of the lighter fraction of the oil would evaporate and emulsify and some microbial decomposition would occur at this time of the year (April).

In Case 13, 2,690 barrels of oil are spilled at the entrance to Winyah Bay at South Island Bend in late spring during average streamflow conditions at slack low tide. The spilled oil would move into Winyah Bay. Of the five less than total loss oil spill scenarios, this spill is potentially the most damaging because of the volume of oil spilled and its trajectory. The oil spill would make landfall within 1.5 hours on North Island and travel northward to Marsh Islands, Pumpkinseed Islands and Mud Bay. On the shoreline, it would encounter tidal flats and marshes. Where the tidal flats are exposed and compacted, most oil would not adhere to or penetrate into the sediments. However where the sediments are not compacted, as is the case throughout most of Winyah Bay, the oil would penetrate and could persist for years. During the first 10 days, one quarter to one half of the oil could evaporate and emulsify. Emulsification would increase the area of impact. Much of the remainder, minus the portion washed up on shore, could adhere to suspended sediments or be subject to direct dissolution, and sink to the bottom. The Mud Bay region is a low energy environment consisting mostly of silts and clays. Late spring and summer are seasons of high microbial decomposition, which would result in the biodegradation of much of the oil while in the water column and on the bottom surface.

In Case 14, 14,000 barrels of crude oil are spilled at the Winyah Bay entrance at the North Island jetty. This would occur in December during mid-flood tide with winds from the south. During this time of year, microbial degradation is at a minimum. Based on spill trajectory modeling, it is anticipated that high river discharges would prevent the spill from penetrating Winyah Bay beyond the narrows in the vicinity of Cat Island. In this high energy environment, the bottom sediments consist predominantly of sand size material (75 to 100 percent; Colquhoun, 1973). Consequently it is not expected that the interaction of oil and clay particles would play a significant role in flocculation of spilled material, due to the general absence of clays. Nevertheless, in this high salinity environment, oil alone could flocculate and settle to the bay bottom. The oil deposited near the bay entrance, where the coarse-grained sediments are exposed to rapidly moving currents, would not persist because of the action of the currents. The lighter fraction of the crude oil would be subject to evaporation and emulsification. Oil

that reached the shoreline would penetrate marshy areas and persist. Oil reaching compacted tidal flats or fine-grained beaches, as exist on North Island, would not penetrate the surface (Gundlach and Hayes, 1978).

In Case 15, 140,000 barrels of crude oil are spilled 6.4 km (four mi) east of the Winyah Bay harbor entrance channel during slack low tide with 26 knot (30 mph) winds from the northeast. It is anticipated that the spill would foul the shoreline from South Island southward to Cape Romain. Where the shoreline is marshy, oil could penetrate the sediments and become persistent. Oil also could penetrate course-grained sand beaches. The most significant problems associated with this spill would occur when the crude oil enters Cape Romain Harbor and makes landfall in the extensive marsh areas. The funnel-shaped entrance to the harbor effectively would direct the spill into the Romain River and surrounding marshlands. An unknown but significant volume of oil could be expected to persist in that coastal environment for years after it penetrates the sediments. Although the Cape Romain area would suffer the most significant impacts, a large but undefined volume of the spill would oxidize, emulsify, evaporate, be degraded by microbial activity, become incorporated in the water column or be deposited in the offshore bottom sediments.

In Case 16, 140,000 barrels of oil are spilled 13 km (eight mi) east of the Winyah Bay harbor entrance channel, east of the South Island Bend during slack low tide and under conditions of average flow in the Pee Dee, Waccamaw and Sampit Rivers. This would occur with 26 knot (30 mph) gale-force winds from the southeast. The spill would occur at a point offshore where a portion of the spill would be entrained by the prevailing current and carried to the beaches of North Inlet. That portion carried to the oceanfront beaches of North Island would encounter fine-grained quartz-sand beach material. The texture of this material is such that oil would not penetrate measurably into the sediment, thus facilitating mechanical cleanup. Without cleanup, oil could persist for several months.

Oil entering the North Inlet would flow into the North Island and Waccamaw Neck Creeks along with high salinity water (32 ppt). In the low energy environment of the creeks there is a preponderance of fine-grained material. As a result, the high salinity would allow oil to flocculate alone and precipitate to the bottom. The spilled oil entering the marsh areas could be expected to penetrate into the marsh sediments and persist for years. Perhaps as much as 50 percent or more of the total spill volume would evaporate or be transported down current, as in the case of the Amoco Cadiz spill discussed previously.

In Case 17, a major spill of 60,000 barrels of refined oil occurs at the tank farm associated with the proposed Harmony Plantation siting alternative. A large portion of the refined oil would penetrate into soils in the low-lying areas around the spill site, particularly the soils of the marshlands if they were reached. Any oil running through Turkey and Pennyroyal Creeks would cause accumulation into sediments on the shorelines and eventually bottoms of these creeks. Upon reaching the Sampit River, both shorelines from the vicinity of Pennyroyal Creek to Winyah Bay would receive oil. Some oil would be stranded in wetlands surrounding the Sampit River as the tides ebb. This oil would be expected to penetrate and persist in these areas. The remainder of the impact to sediments and sediment transport would be similar to those discussed for Case 6, however, toxicity may generally be greater.

(b) Data Limitations. An understanding of both sediment distribution and sediment transport mechanisms is essential to fully understand the effects of the construction and operation of the proposed CRDC oil refinery on the Sampit River in Georgetown, SC. This is because spilled oil, refined products, and

process water contaminants may be introduced through various mechanisms into the water column and ultimately into the bottom sediments of the rivers and Winyah Bay because of various physicochemical interactions between the oil, refined products or other contaminants and the sediments. This can occur with sediments in the water column or on the bottom and is especially true of clay-sized particles, as discussed earlier.

Although sediment transport studies have not been done and the only comprehensive bottom sediment distribution study was performed in 1971, the evaluation in this EIS of the environmental consequences of the proposed refinery is deemed sufficient by the Corps of Engineers to enable it to determine whether or not it is in the public interest to issue the permit for the underwater oil pipelines.

(5) Impacts to Water Quality

(a) Baseline Petroleum Hydrocarbons in Winyah Bay. Baseline petroleum hydrocarbons were measured in surface waters (top 20 cm) in a study by Bidleman and Svastits (1983). They found that oil concentrations in Winyah Bay are very low and, as such, are more typical of continental shelf waters than industrialized estuaries. The highest measured petroleum hydrocarbon values were found in the Sampit River and the lowest values were found in Winyah Bay.

(b) Characteristics of Crude Oil in Water. In the event of a crude oil spill, many physical processes serve to modify or alter the condition of spilled crude oil within the water column. These processes include evaporation (which tends to enrich certain heavy constituents), emulsification, solubilization, photo-oxidation (which contributes to solubility), precipitation by adsorption to suspended particles, biodegradation (by bacteria and fungi), up-take by estuarine organisms, and absortion by oleophilic substances such as detritus and marsh vegetation. Table VII.B-24 summarizes the timing and fates of various percentages of a crude oil slick. The reader should keep in mind that the source of crude oil for the proposed refinery contains a larger fraction of tar residue and settleable substances and a smaller fraction of volatile substances than does south Louisiana crude oil.

The formation of a surface slick by crude oil has several important consequences that affect physical and biological processes at the water surface. These include alteration of surface tension, reduced light penetration and inhibition of the air-to-water transfer of gases such as oxygen and nitrogen. Thin surface films of crude oil can persist up to 30 days after a spill takes place, with sediments and marshes acting as secondary sources of oil. The formation of a slick greatly increases the surface of the crude oil, which leads to enhanced evaporation of low-molecular weight volatile components into the atmosphere and enhanced dissolution of water-soluble components into the water column. Higher molecular weight components of crude oil are strongly sorbed to particulate matter and are removed from the water column by sedimentation. Surface turbulence due to wind, waves and currents may cause the suspension of oil droplets in the water column and sediments. Sediments contaminated with oil could then release some petroleum hydrocarbons and heavy metals to the water column. In addition, the incorporation of oil into sediments inhibits the normal uptake and release of soluble nutrients, metals and organic substances to the water column.

Additionally, oil can form oil-in-water emulsions that are relatively stable. All crude oils contain surface-active agents that foster the formation of emulsions (U.S. Maritime Administration, 1973). The formation and stability of oil-in-water emulsions in natural environments is enhanced by the variety of emulsifying agents, such as proteins, gums, clays and silts, found in most aquatic systems. The formation of oil-in-water emulsions greatly increases the amount of oil in the water column, since emulsification is not dependent on the solubility of oil in water.

TABLE VII.B-24

SIGNIFICANCE OF PROCESSES FOR CONVERTING SOUTH LOUISIANA CRUDE OIL

Process	Time Scale, Days	Approximate Percentage of South Louisiana Crude Oil Slick Volume Converted
Evaporation	1 to 10	45
Dispersion	1 to 30	10
Dissolution	1 to 10	1
Oxidation	3 to 365	5
Settling and Biodegradation	10 to 365	25
Tar residue	10 to 365	1
Other or unaccountable	---	10 to 15

SOURCE: U.S. Department of the Interior, 1983

(c) Petroleum Hydrocarbons from Crude Oil in Water. Of the various components of crude oil that can enter the water column, the water-soluble fractions are the most dangerous to aquatic life. Of the major components of oil, the C_5 to C_8 straight-chain paraffins and some liquid aromatics have appreciable solubilities in water. The C_4 and lower paraffins, while soluble, do not persist in water very long due to their low partial pressures in air. Analyses of water extracts of crude oils and kerosene by gas chromatography and mass spectophotometry indicate that the extracts are composed primarily of lower boiling-point (160°-200°C) aromatic hydrocarbons, i.e., substituted benzene and napthalenes (Blumer et al., 1973). Aromatic hydrocarbons are the most abundant and most dangerous fraction (Blumer, 1969). Low boiling-point aromatics, e.g., benzene, toluene, xylene, are acutely toxic to both man and all lower organisms (Blumer, 1969). The high boiling-point aromatics of crude oil include the alkylated 4- and 5-ring aromatics which have been indicated as the carcinogenic agents in tobacco tar (Halstead, 1972). Blumer has suggested that all hydrocarbons boiling between 300 and 500°C should be viewed as potentially carcinogenic.

In addition to hydrocarbons, crude oil contains at least two percent of oxygenated, sulfuretted and nitrogenized hydrocarbon derivatives that are quite soluble in water. Oxygenated and nitrogenized hydrocarbon derivitives are more susceptible to microbial attack than are pure hydrocarbons (McKee, 1956) and, since attack occurs at the oil-water interface, emulsions and suspensions are more readily degraded than are tar balls or clumps of oil.

(d) Water Quality Effects Relative to Public Health. In addition to the specific water quality effects of crude oil described in the foregoing section, some additional effects related to health considerations merit discussion. In the event of a spill in the upper Winyah Bay estuary, certain conditions for factors such as winds, tidal currents, river discharge and saltwater/freshwater interface favor crude oil or refined product movement up the Waccamaw, Pee Dee and Black Rivers. The most serious public health aspect of oil pollution in rivers is the possibility of contaminating public drinking water supplies, including the possible harmful effects of oil pollution on water treatment processes.

The movement of emulsified oils from an oil spill can be expected to follow the movement of the bay waters up the various tributary rivers during flood tide. Using the location of the saltwater/freshwater interface as a marker for the front of bay waters allows a determinatin to be made of the approximate distance upstream the oil could travel. Johnson (1970) characterized the location of the freshwater/saltwater interface in Winyah Bay by measurements of specific conductance under varying freshwater inflow conditions. Using the U.S. Geological Survey value of 900 micromhos per centimeter as defining saltwater, the interface, and thus possibly oil, could be expected to reach up to 15.3 km (9.5 mi) on the Waccamaw and Pee Dee Rivers and up to 13.7 km (8.5 mi) on the Black River.

By plotting specific conductance against steam discharge, Johnson (1970) extrapolated the SWI at low flow (3,000 cfs) to a point upstream on the Pee Dee and Waccamaw at Mile 16 and on the Black at Mile 13 above the mouth. Johnson stated (personal communication, 1984) that he felt that these were conservative figures from the point of view of freshwater supplies. That is, it should be safe to install a freshwater intake at or above Mile 16 on the Pee Dee and Waccamaw and Mile 13 on the Black River. At present, no freshwater intakes exist below these points on the rivers (Meetze, personal communication, 1984).

Of greatest concern are the amounts of polycyclic, carcinogenic hydrocarbons that might contaminate water supplies. However, the human intake of polycyclic, carcinogenic hydrocarbons from drinking water is expected to be a fraction of the body's total intake, the majority coming from polluted air (Martin 1971). Nevertheless as Martin notes "it is a general rule that carcinogens in the environment should be kept to as low a figure as possible and, on these grounds, every effort should be made to prevent contamination of drinking water supplies by oil."

(6) Mitigative Measures

(a) Spill Prevention, Control and Countermeasures Plan. The Federal Clean Water Act contains a special provision to control the discharge of oil. In addition, this Act develops a national contingency plan for removal of oil that has ben discharged.

The USEPA and the U.S. Coast Guard are the federal agencies with primary enforcement responsibility for oil pollution prevention. The Coast Guard is generally responsible for regulating the transportation of oil by pipeline or ship and the transfer of oil to or from a ship. Coast Guard regulations concerning oil pollution prevention for marine oil transfer facilities are found in 33 CFR 154. These regulations detail requirements for the type of equipment to be used in transferring oil, facility operating procedures and the preparation and availability of records. Coast Guard regulations concerning the unloading and transfer of oil are found in 33 CFR 155 and 33 CFR 156. These regulations include details on vessel equipment to be utilized, transfer procedures, inspection and testing procedures, notification procedures, and records to be maintained. Regulations found in 33 CFR 157 detail procedures for the protection of the marine environment pertaining to tank vessels carrying oil in domestic trade. This regulation includes requirements for the design of the vessel and equipment utilized, operation of the vessel during the delivery and transfer of the oil, and inspection and approval procedures which the Coast Guard utilizes to enforce these regulations. These regulations apply to both domestic and foreign vessels that enter any U.S. port.

USEPA regulations concerning the preparation and implementation of a Spill Prevention Control and Countermeasure Plan (SPCC) for oil facilities are found in 40 CFR 112. This plan is to be prepared within six months of the date the facility begins operation and shall be implemented as soon as possible, but not later than one year after the facility begins operations. The SPCC Plan also addresses containment and/or diversionary structures or equipment to prevent discharged oil from reaching a navigable water course. In addition, criteria for state, local and regional oil-removal contingency plans appear in 40 CFR 109. Proposed regulation 40 CFR 111 sets forth the procedures for voluntary removal of oil and hazardous substances by the discharger. This proposed regulation contains detailed procedures to follow concerning removal of a spill, mandatory provisions to be adhered to, liability of the discharger, and civil penalties. USEPA regulations contained in 40 CFR 113 and 40 CFR 114 detail the liability limits for small onshore oil storage facilities and the civil penalties for violations of oil pollution prevention regulations.

All facilities having a potential for an oil spill are required to prepare a detailed Spill Prevention Control and Countermeasure Plan (SPCC). The SPCC plan is required to be updated every three years. In order to ensure compliance with this requirement the South Carolina Department of Health and Environmental Control will randomly investigate facilities to determine if SPCC plans have been prepared and if key personnel are aware of and understand the plan. These investigations will be conducted both singularly and collectively with USEPA Region IV personnel on all

non-transportation related onshore and offshore facilities which, due to their locations, could reasonably be expected to discharge oil in harmful quantities, as defined in Part 110 of 40 CFR. The DHEC has stated that it will devote some effort to reinspection of facilities.

The SPCC plan is required by 40 CFR 112 to contain site specific, detailed information. The USEPA has issued the following guidance for certain information areas for preparers of SPCC plans:

AREA I. Biographical and Geographical Information (Reference Sections 112.3 (d) and 112.4 of 40 CFR 112)

a. Name of facility, mailing address and location (Highway number, street, etc.) and phone number;

b. Owner(s) and/or operator(s), phone number(s) - business and home. Any other emergency phone contacts;

c. Storage capacity and types of fuel;

d. Date began operation;

e. Schematic diagram of facility showing tanks, buildings, roads, ditches, direction of flow and distance to nearest stream(s); and

f. Certification by Professional Engineer.

AREA II. (Reference Section 112.7(a) and (b) of 40 CFR 112)

This area is concerned with past spills and their causes and potential causes of future spills. Listing of past spills and potential future causes of spills should provide guidance in developing prevention techniques. When addressing future sources of spills think in terms of the worst possible conditions (weather, time, personnel present, etc). It might also be helpful to determine the maximum spillage possible from each source. Some often overlooked areas where spills occur are: vent pipes from tanks, loading and offloading areas or facilities, piping to storage tanks, fuel pumps, boiler rooms, sumps and packaged oil storage areas.

AREA III. (Reference Section 112.7(c) and (e) of 40 CFR 112)

The next area deals with a listing or discussion of the actual prevention measures employed or planned (with time schedule). This should include such things as routine maintenance, dikes, training, security, curbing, speed breakers, etc. Anything which prevents oil from being spilled and reaching U.S. waters is a form of prevention. The SPCC regulation offers many good suggestions and guidelines in this area.

AREA IV. (Reference Section 112.7(d) of 40 CFR 112)

A contingency plan can never be substituted for a prevention plan except as provided for in Section 112.7(d) of the SPCC regulation. However, contigency planning should be an integral part of any prevention plan. A contingency plan should tell you what to do, who to call, where to get help, etc., in the event a spill should occur. Often when a spill occurs management personel are not available to make the immediate decisions required to contain a spill and initiate cleanup activitties. Therefore, a plan of action is imperative so that John Doe can take prompt correc-

tive action. Consider the contigency plan as being a "battle plan" containing phone numbers of state and federal agencies, contractors, fire departments and other sources of help or equipment. Also the plan should discuss actions to be taken to control and clean up any spill.

The American Petroleum Institute (1981) offers the following guidance for preparers of SPCC plans:

- Have policy and purposes consonant with Section 311 of the Clean Water Act and the National Contingency Plan;
- Address the five phases of oil spill response spelled out by the National Contingency Plan;
- Clearly assign responsibilities to appropriate personnel and organizations;
- Encourage the participation of state and local government along with environmental, scientific, and industry organizations;
- Be site-specific and suited to local conditions and problems;
- Have procedures for updating the plan on an annual basis as well as after major spills;
- Contain pertinent and accurate environmental baseline data;
- Coordinate with oil spill prevention plans and procedures;
- Have a clear, easy to use format;
- Describe location, capability, and limitations of cleanup and containment equipment;
- Discuss expected behavior of petroleum spilled along different sections of the river, shore, or coast;
- Provide for training programs, sessions, and exercises;
- Detail how communications will be maintained among all parties during response operations;
- Describe procedures for handling public relations and the media;
- Address human safety issues;
- Identify high-risk areas and operations;
- Identify and rank vulnerable resources for protection;
- Detail actions for minimizing spill damage to natural resources and the environment:
- Develop action plans for responding to likely and major pollution incidents;

- Have general guidelines for determining when cleanup operations should cease;

- Detail procedures for damage assessment and restoration;

- Have provisions for responding to spills under extreme weather conditions; and

- Pre-arrange response capability for a worst case spill.

The applicant has indicated that the contingency plan for the proposed refinery will be a comprehensive plan which will be tailored to fit the environment in which it will be used. This involves examining physical processes (winds, currents, etc.) so that the fate of spilled oil may be predicted, and identifying areas that are particularly vulnerable to oil spill damage (biologically sensitive areas). Protection systems will be adapted for each area in which a spill could occur and the plan practiced through regular drills. This type of planning decreases the number of decisions that must be made after a spill occurs, thereby reducing both the reaction time and environmental damage.

The plan will provide procedures for actions to be taken in the event of a spill, including (1) discovery, identification and notification; (2) containment and/or collection; (3) removal or mitigation; and (4) disposal. CRDC has expressed a commitment to properly train its employees in oil spill prevention measures and actions to be taken in the event of a spill. All personnel would be on 24-hour call for oil spill emergencies. Employee training would concentrate on measures to control the source of spills and contain spills. This would include call out and practice sessions and stress practical rather than theoretical aspects of oil spill control and containment. The applicant's SPCC Plan for the proposed refinery is provided in Appendix A.

(b) Oil Spill Mitigative Measures. Physical measures to mitigate the effects of oil spills on surface waters include those designed to reduce the frequency of occurrence or severity of the spill and those designed to reduce the effects of the spill on the environment. Some measures which may be used at the CRDC Georgetown Refinery to help prevent spills include:

- installation of piping above ground for ease of inspection;

- emergency cutoff valves on both pipelines under the Sampit River;

- regular tank leak detection and prevention techniques;

- high oil level alarms on ship and shore tanks or loading and unloading docks with oil levels monitoring devices;

- protective coatings and cathodic protection for pipelines;

- training of personnel on plant and pipeline operations and maintenance;

- frequent material and equipment inspections;

- coordinated tanker/barge traffic including continuous bridge-to-bridge communications;

- daylight transits only for oil transport vessels;

- no anchorage zone near pipeline crossing;

- utilize survey results to determine safest pipeline route; and

- use of port pilots on vessels entering the Bay.

Measures which may be used to reduce the environmental impact of an oil spill in Winyah Bay include:

- installing containment booms around ships and barges during loading and unloading operations;

- maintaining fixed or portable skimmers nearby for rapid clean up of spills;

- training of personnel on the SPCC Plan;

- ensuring that the SPCC Plan can be implemented quickly by continual appraisal of the availability of clean up assets and subcontractors;

- utilizing the Winyah Bay oil spill trajectory model to predict oil spill movement;

- protection of sensitive areas and inlets by containment boom or other such methods, where possible; and

- careful consideration for choice of cleanup procedure to ensure that greater damage is not imposed by cleanup.

(c) Oil Spill Containment Measures.

(i) Emergency Response Measures. South Carolina DHEC has developed an Emergency Respose Section (ERS) to respond to environmental emergencies related to oil and hazardous materials. The ERS coordinates emergency response activiites with the USEPA, the USCG, the South Carolina Department of Highway and Public Transportation, the South Carolina Water Resources Commission and the South Carolina Wildlife and Marine Resources Commission. DHEC has developed a State Contingency Plan for oil and hazardous materials. This plan has been approved by DHEC's board, and copies have been distributed to fire departments, law enforcement, Civil Defense, SC Highway Department, SC Highway Patrol, industries, jobbers, engineering firms, interested citizens, and other governmental agencies. Meetings have taken place with the foregoing agencies to develop spill cooperatives and response assistance groups.

DEHC has established a 24-hour telephone number so that spills can be reported. The number is 758-5531. Between 8:30 am and 5:00 pm this number is manned by personnel in the Emergency Response Section; after 5:00 pm an answering service intercepts all calls, then contacts the person who is on call to respond to the spill. DHEC has also established a spill response team in each of the state's twelve districts in order to enhance its response time and provide for better local coordination through on-scene coordinators. The Emergency Response Section has a computerized data system known as Oil and Hazardous Material Technical Assistance Data System (OHMTADS). This system is designed as a further source of information and technical assistance which can be utilized during a serious spill situation. The DHEC states that in the future it may be feasible to transport a portable OHMTADS terminal - telephone coupler apparatus to the scene of a spill.

In the event of an oil spill, CRDC personnel would inform the Emergency Response Section of DEHC and the SPCC plan would go into effect. A variety of factors affect the feasibility of spill response activities. The following discussion of oil spill response feasibility, supplemented with specific information concerning the proposed Georgetown Refinery, is taken largely from the Oil Spill Contingency Plan prepared for Brunswick Energy Company (BECO) by Woodward-Clyde Consultants in February of 1981 for the BECO Refinery at Wilmington, North Carolina.

(ii) Emergency Response Feasibility. Physical control and recovery of spilled oil is generally limited to a narrow range of environmental conditions. Operation of cleanup equipment beyond its design specifications is generally unsuccessful and often dangerous to the operators. To assess the feasibility of an emergency response situation, the following conditions must be considered:

- prevailing meteorological, hydrological, and oceanographic conditions;
- physical properties of the spilled oil;
- access to threatened or contaminated sites; and
- logistics of oil spill response.

Effects of Meteorological, Hydrological, and Oceanographic Conditions. Visibility can become a limiting factor during fog, haze and rain, and at night. It is limiting primarily with regard to tracking of spill movement. Response vessels equipped with radar may be able to operate safely in low visibility situations, and helicopters may be successful in night tracking of slicks if equipped with lights. However it is generally difficult, if not impossible, to effectively clean up an oil spill during heavy rain, high winds, fog, freezing temperatures, or in the dark (Whitebloom, 1976). Unfortunately these are the adverse circumstances under which spills are more likely to occur.

Both extreme depth and extreme shallowness can limit response operations. Static anchoring of booms will probably be ineffective in depths greater than approximately 15 m (50 ft). Vessel operations (including outboard vessels) are generally limited to water greater than 0.6 to 0.9 m (two to three ft) in depth. In extremely shallow or intertidal areas, such as Mud Bay, booms may ground and poor performance can be expected.

Sea state limits the effectiveness of containment booms and oil skimmers for various sea states. Generally, even containment and skimming equipment rated for open sea conditions quickly loses effectiveness once a sea state of 3 on the Beaufort scale is surpassed. Therefore, if a sea state of 4 (i.e., breaking waves over five feet) or greater is present in a spill area and these conditions are predicted for several days, mechanical containment and cleanup techniques would probably not be effective in controlling the spill. If strong winds continue long enough from a southeasterly direction in Winyah Bay, wave heights could build to levels that would inhibit spill cleanup.

High currents primarily affect boom performance. Generally, boom failure can be expected to occur with currents exceeding 1 to 1.5 knots (conventional deployment). Used in free-floating or diversionary modes, acceptable performance can be obtained in faster current situations. Currents in Winyah Bay have been found to exceed 1.5 knots (May 1982; May, personal communication, 1984); therefore, normal boom deployment may not be effective in certain parts of the estuary.

Physical Properties of Spilled Oil. The ability of a skimmer to recover spilled oil is affected by the physical state of the oil. Woodward-Clyde Consultants developed the following classification specifically for use in oil spill response situations. The classification system considers general toxicity, physical state, and changes with time and weathering.

Class A: Light, volatile oils (most CRDC refined products)

Class B: Non-sticky oils

Class C: Heavy, sticky oils (Bachequero crude)

Class D: Nonfluid oils

Representative oils, diagnostic properties, and physical-chemical properties for each of these classes are summarized in Table VII.B-25. It is essential to recognize the dynamic nature of this classification. Some oils can rapidly undergo extensive modification of properties; others may remain relatively unaffected over longer periods of time. For this reason, a given oil can and often will change characteristics sufficiently to be placed in more than one of the above oil classes over time. In addition, oil can change with the time of day, becoming fluid during exposure to sunlight and solidifying during night and morning hours. High-viscosity, nonflowing, or emulsified oils (Class D and some Class B and C oils) generally require the use of belt-type skimmers. Viscous and nonfluid oils also cause pumping and storage problems.

Response feasibility for certain areas in Winyah Bay may be governed by accessibility to threatened or contaminated sites. Accessibility may be limited by water depth, roads, boat launching sites or helicopter landing sites. The environs of Winyah Bay contain many wetland areas where access is difficult or impossible; thus, cleanup operations could be inhibited by the terrain of the Winyah Bay area. Figures VII.B-21 and VII.B-22 summarize the decision-making processes pertaining to spilled oil with respect to meteorological, hydrological, and oceanographic conditions; physical properties of spilled oil; and access to contaminated sites.

Logistics of Oil Spill Response. The final factor which must be considered in assessing the feasibility of immediate oil spill control and oil recovery is the availability and response time of sufficient containment and recovery equipment to adequately handle the spilled oil.

CRDC has indicated that additional measures will be taken that will support and accentuate the usefulness of the Spill Prevention, Control and Countermeasures Plan. CRDC will attempt to form an oil spill cooperative with other petroleum handlers in the Georgetown area, whereby the participants may "pool" their resources for oil spill cleanup and containment equipment. Each member would contribute to the cooperative on the basis of the volume of petroleum products handled. Currently the only other petroleum handler in Georgetown Harbor is the Hess Oil Company storage facility. Formation of a cleanup cooperative in the Georgetown area would be unlikely with only two petroleum handlers, particularly since Hess Oil Company traditionally maintains its own spill response equipment and does not usually join co-ops. The refinery will have, on-site, enough containment booms to completely encircle a tanker or barge and/or to completely boom the Sampit River Channel, and a sufficient size and number of boats to tow the boom, transport personnel, and move sorbents and miscellaneous equipment to a spill site. CRDC has indicated that floating booms and oil sorbents would be on hand to prevent the oil spill from spreading and to aid in the pickup of oil from the water surface. Also,

TABLE VII.B-25

SPILL RESOPNSE CLASSIFICATION

Field-Determined Oil Type	Designation	Representative Oils	Diagnostic Properties	Physical/Chemical Properties
A	Light volatile oils	Distillate fuel and most light crude oils	Highly fluid, usually transparent but can be opaque, strong ordor, rapid spreading, can be rinsed from plant sample by simple agitation.	May be flammable, high rate of evaporative loss of volatile components, assumed to be highly toxic to marine or aquatic biota when fresh, tend to form unstable emulsions, may penetrate substrates.
B	Non-sticky oils	Medium to heavy paraffinbase refined and crude oils	Moderate to high viscosity, waxy or oil feel, can be rinsed from surfaces by low pressure water flushing.	Generally removable from surfaces, penetration of substrates variable, toxicity variable. Includes water in oil emulsions.
C	Heavy sticky oils	Residual fuel oils; medium to heavy asphaltic and mixed-base crudes	Typically opaque brown or black, sticky or tarry, viscous, cannot be rinsed from plant sample by agitation.	High viscosity, hard to remove from surfaces, tend to form stable emulsions, high specific gravity and potential for sinking after weathering, low substrate penetration low toxicity (biological effects due primarily to smothering). Will interfere with many types of recovery equipment.
D	Nonfluid oils (at ambient temperature)	Residual and heavy crude oils (all types)	Tarry or waxy lumps.	Nonspreading, cannot be recovered from water surfaces using most conventional cleanup equipment, cannot be pumped without pre-heating or slurrying, initially relatively nontoxic, may melt and flow when stranded in sun.

Source: Woodward-Clyde Consultants, 1981

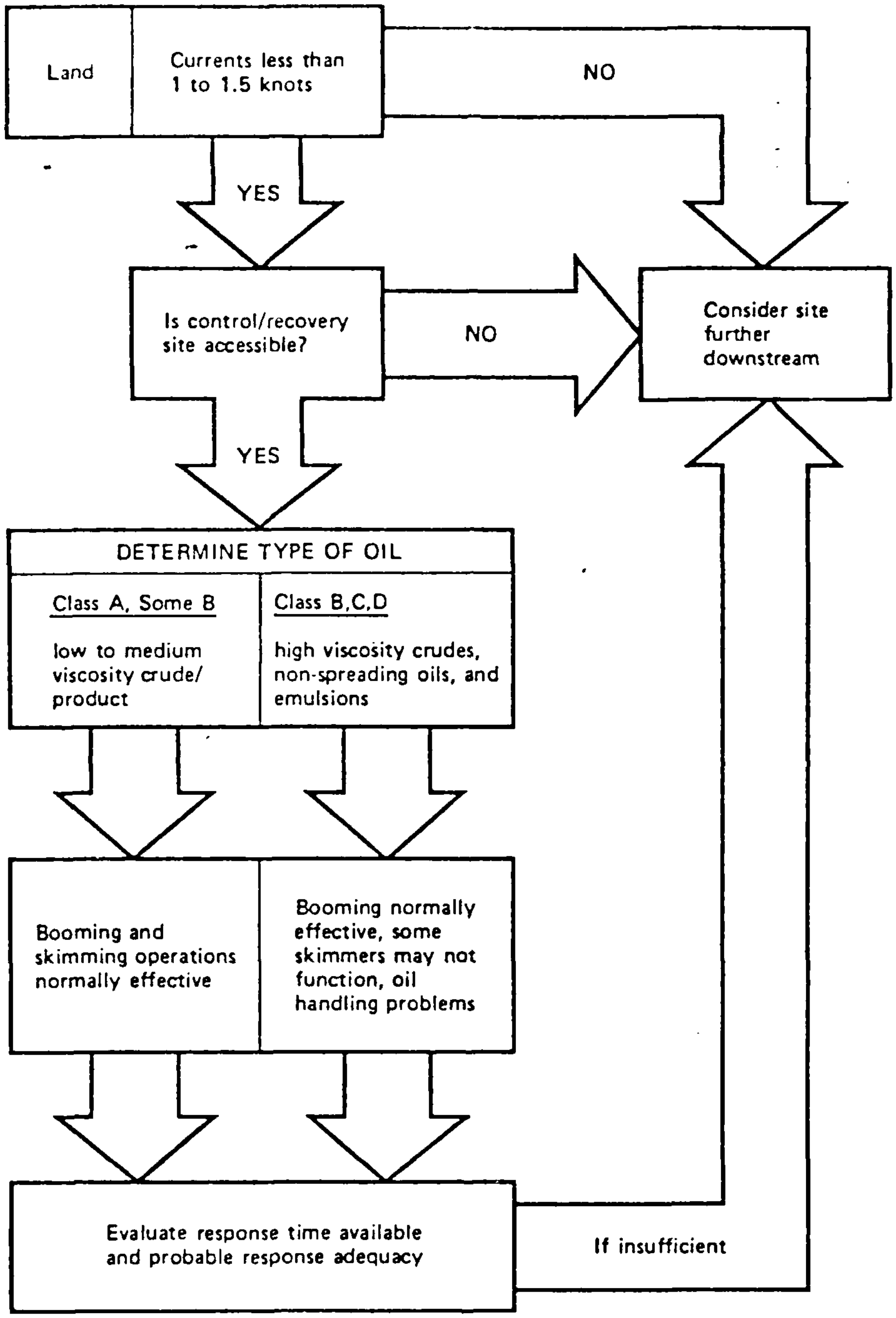

Figure VII.B-21. Assessment Guide for Spill Control and Recovery Inland
Source: Woodward-Clyde Consultants, 1981

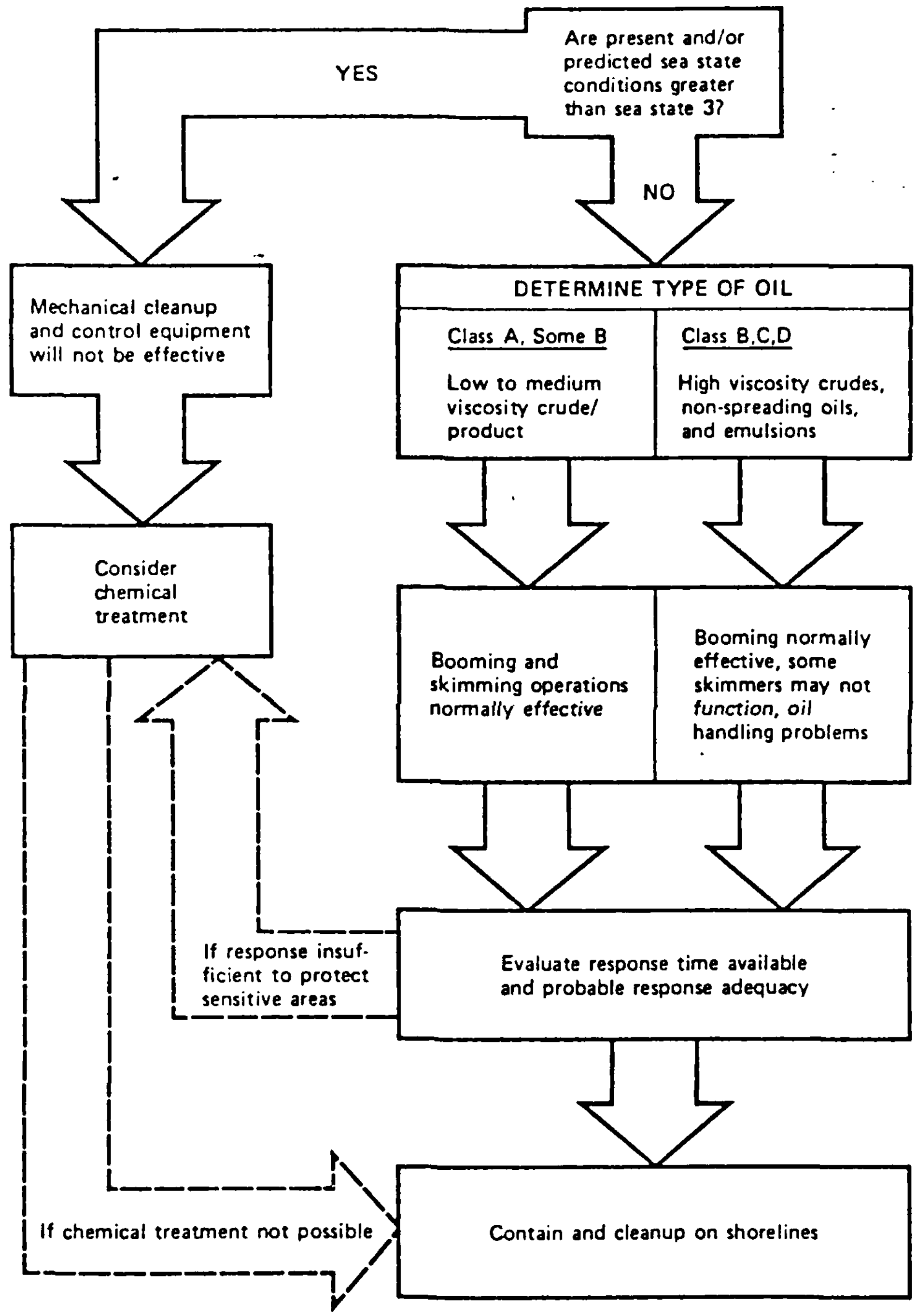

Figure VII.B-22. Assessment Guide for Spill Control and Recovery at Sea
Source: Woodward-Clyde Consultants, 1981

surface skimmers and pumps would be available for picking up the oil and sorbent from the water. Recovered oil, water and sorbent would be pumped to a storage container and transported to the refinery, where the oil would be recovered. The water would be treated in the refinery waste treatment facility and the sorbent would be disposed of in an approved landfill. Burning agents, sinking agents, biological agents, dispersants, or emulsifiers would not be used unless prior permission was obtained from the South Carolina Department of Health and Environmental Control and USEPA, or unless there is an immediate threat to human life. The use of these substances is controlled under Council on Environmental Quality (CEQ) regulations found in Annex X to 40 CFR 1510 (as prepared by the USEPA pursuant to Executive Order 11735).

Several other sources of equipment and support services, including local and regional oil spill contractors, labor pools, oil spill cooperatives, government agencies, and other equipment contractors and suppliers, are identified in this section. A comprehensive equipment listing can be obtained in the USCG SCIM Report available from the U.S. Coast Guard, Fifth District, Portsmouth, VA, at (804) 398-6231. There are several oil spill cooperatives on the east coast (Table VII.B-26), the closest of which is Clean Land and Harbors Inc. in Wilmington. Clean Land and Harbors Cooperative was organized to supplement contractor services by providing equipment, expertise, and direction for oil spill cleanup operations. In the event of a major spill, local contractors perform the majority of the cleanup operations and Clean Land and Harbors provides equipment and supervision. Table VII.B-27 lists the equipment of Clean Land and Harbors and its member companies. In the event that required containment or cleanup operations exceed the capabilities of CRDC, Clean Land and Harbors, Inc. could deploy cleanup and/or containment equipment to a spill in Winyah Bay within five hours.

CRDC also has indicated that they would enlist the services of an outside contracting firm which specializes in oil spill containment and cleanup to supervise work in the field and perform cleanup operations in the event that a spill exceeded its capability. Oil spill cleanup contractors within a reasonable distance of Winyah Bay and their equipment are listed in Table VII.B-28. Sea Hol Contracting Company is Charleston, South Carolina is the closest cleanup contractor to Winyah Bay and could deploy their equipment within three hours. Industrial Marine Service could deploy its boom from Morehead City, North Carolina within six hours. Equipment from Industrial Marine Service in Norfolk, Virginia and O.H. Materials in Roswell, Georgia could reach Winyah Bay within twelve hours.

In addition to the cooperatives and private companies listed above, the U.S. Coast Guard maintains the Gulf Coast Strike Team in Bay St. Louis, Mississippi, and the Atlantic Strike Team in Elizabeth City, North Carolina. Georgetown is in the Gulf Coast Strike Team's district. The equipment and expertise of the stike teams are, however, strongly oriented towards emergency lightering of stricken vessels but they will respond to most spills in an advisory capacity. Personnel from the Gulf Coast Strike Team could arrive in Georgetown four to eight hours after a spill occurred; equipment would reach Winyah Bay within 24 hours. The Elizabeth City strike team could respond to a spill in Winyah Bay at the request of the Coast Guards' Marine Safety Officer in Charleston. Response time would be approximately ten hours.

Throughout the following discussion the reader should be aware that offshore containment/cleanup operations are considered to be "marginally effective", with recovery rates of five to 15 percent of oil spilled. Inshore containment/cleanup operations are estimated to result in 20 to 50 percent recovery of material moving into the contained/cleanup area (U.S. Department of the Interior, 1983). For

Table VII.B-26. EAST COAST OIL SPILL COOPERATIVES EQUIPMENT INVENTORY

Cooperative	Boats	Booms	Skimmers	Other
Clean Atlantic Associates South Atlantic Area Brunswick, GA (912) 265-2485		1000'-8' Kepner Compact 1500'-36" Kepner Compact	2-Fast Response Model 1 2-Fast Response Model 2	1-Helicpoter dispersant applicator units 3-Vessel dispersant application units
Clean Atlantic Associates Mid-Atlantic Area Davisville, RI (401) 884-3501		1000'-8' Goodyear BT 1000'-8' Kepner Compact 1500'-36" Kepner Compact	2-Fast Response Model 1 2-Fast Response Model 2	2-Helicopter dispersant application units 3-Vessel dispersant application units
Clean Harbors Cooperative Perth Amboy, NJ (201) 738-2438	10-22 ft, 170 hp Deployment 2-27 ft, 300 hp LCM 2-34 ft, 300 hp Work	20,000'-19" Optimax 6,000'-20" Kepner Supercompactible 3,000-30" Kepner Supercompactible	1-JBF Model 3003 1-JBF Model 3001 3-CSI Model 29DPT Oil Mop	Trailers for boom & boats
Delaware River Cooperative Philadelpia, PA (215) 339-7233		12,000'-30" Kepner	1-JBF Model 3001*	
Delaware Bay Cooperative Lewis, DE (215) 525-8919		3,000'-30" Kepner*	1-JBF Model 5001	Dracone 10,000 gal. portable oil storage tank.** Kepner Transvac recovery system.
Clean Caribbean Cooperative E. Boston, MA (617) 567-3720	1-27 ft Slickbar folding work boat	3,000'-19" Slickbar MK 9	2-Slickbar Transvac Systems	

*Owned by ARCO and not part of COOP inventory but may be available in spill situation.
**To be purchased.

TABLE VII.B-27

CLEAN LAND AND HARBOR, INC. AND MEMBER COMPANY EQUIPMENT INVENTORY

Company	Boats	Booms	Skimmers	Other
Clean Land & Harbor, Inc. 530 North Third Street Wilmington, NC 28401 (919) 762-4232 (24 hrs)	1-50 hp outboard 1-Boom boat 2-10'x30' barges	600' of 7" Acme 1000' of 7" Acme	1-electric 1-Lockheed Disc	1-Boom trailer 1-25 watt base station 3-4 channel marine mobile units
Texaco, Inc. River Road Wilmington, NC 28401 (919) 633-0569	1-16', 55 hp outboard w/trailer	600' of 18" Acme		
Exxon Company, U.S.A. River Road Wilmington, NC 28401 (919) 799-0146		350' of 24"		1-portable generator
Hercofina, Inc. U.S. Hwy 421 North Wilmington, NC 28401 (919) 763-9841	1-16', 70 hp outboard w/trailer 1-12' 7 hp	1000' of 18" Acme		
Chevron Asphalt 1704 Woodbine Street Wilmington, NC 28401 (919) 763-8423	1-16', 50 hp outboard w/trailer	400' of 18" Acme		
Pfizer, Inc. (919) 457-5011	1-20', 70 hp outboard			
O.E. Durant, Inc. 520 North Third Street Wilmington, NC 28401 (919) 762-4232	1-Twin engine work boat 1-Single engine work boat			
Exxon Pipeline Company River Road Wilmington, NC 28401 (919) 791-3291	1-9.5 hp outboard			
AMOCO 3345 River Road Wilmington, NC 28401 (919) 799-0483	1-12' boat & motor			
Hanover Towing Point Harbor Wilmington, NC 28401 (919) 763-6274	1-800 hp tug 3-400 hp tugs	100' of 18" Uniroyal		2-2" Air double diaphragm pumps
Kenan Transport U.S. Hwy 421 North Wilmington, NC 28401 (919) 762-3377		75' of 10" Acme		3-3" pumps 3-2" pumps

TABLE VII.B-28

OIL SPILL CLEANUP CONTRACTORS AND EQUIPMENT (REGIONAL)

Contractor	Boats	Booms	Skimmers	Tank Trucks	Hydroblasters
Industrial Marine Service Box 1652 Norfolk, VA 23501 (804)543-5718	1-31' Mop-Cat 1-56' LCM-6 2-36' work boats 1-32' bargeards 2-20' outboards 20-12' to 16' boats	10,000' of 18" 2,000' of 36"	12-Oil Hawg 2-Oil Mop MKII-9	3-5000 gal. vac. 1-3000 gal. detachable unit	2-Hydrolasers
Morehead City, NC		1,000' of 18'			
O.H. Materials ,Inc. 950 Hunter Hill Drive Roswell, GA (404)992-3272	7-14' to 18' work boats	1,000' of 4" to 6" boom 1,000' of sorbent boom		2-1500 gal. vac. 2-decon.	
Sea Hol Contracting Co. P.O. Box 266 Charleston, SC 29402 (803)723-2408	4-14' to 16' work boats 2-jet boats with trailers	3,000' of 12" to 16"	3		

inshore locations, the no-action option may be selected because of concern about the cleanup operations causing excessive damage (Breuel, 1981).

CRDC reports that it could deploy 10 to 15 persons to a spill site within 15 minutes, with an additional 50 persons available within an hour. It is extremely optimistic to expect that even under the most ideal weather conditions, a cleanup crew could mobilize and deploy the water containment devices to prevent the spread of an oil slick in less than an hour. Of the hypothetical spill scenarios modeled in this document, CRDC crews, if deployed within one hour, might be able to contain Cases 2, 3, 4, 5 and 17 within portions of the Sampit River.

Case 1, which occurs on the Waccamaw River, if contained after ninety minutes, would affect two km (1.3 mi) of river from the Harrell Siau Bridge northward. However, strong winds and currents present in the foregoing scenario could prevent effective containment of the spill. Cases 6 and 17 are large spills in the Sampit River occurring near a time of maximum ebb tidal currents, which would limit the effectiveness of containment measures. These spills move into Winyah Bay from one to two hours after occurrence. Therefore, it can be assumed that large quantities of oil would enter Winyah Bay near Sampit Point. These spills would spread north almost to the Harrell Siau Bridge in six hours, and southward to Horse Island after four hours and 15 minutes. Equipment from Sea Hol Contractors could be deployed in time to arrest southward movement of oil past Frazier Point. Because of the extensive length of shoreline rapidly affected by these spills, containment is expected to exceed local capacity. Additional containment and absorbent equipment provided by cleanup contractors may prevent extensive fouling of Belle Isle Gardens and redispersion of large quantities of oil upon the change of tide.

In Case 8 refined product moves northward from Sampit Point, possibly missing the Sampit River and reaching the Pee Dee River after two hours and 15 minutes. The large quantity of refined product in this spill would create an inhalation hazard to cleanup crews and could necessitate evacuation of portions of Georgetown, thus impairing deployment of arriving cleanup crews. The very large oil slick (157,000 barrels) in Case 9, pushed by a gale force wind, would move from its starting point at Frazier Bend to the Harrell Siau Bridge in one hour and 45 minutes. Sea and wind conditions would prevent the effective and safe deployment of any marine containment devices, resulting in maximum contamination of upper Winyah Bay and the Sampit, Pee Dee and Waccamaw Rivers. Arrival and/or deployment of cleanup equipment from several contractors and possibly the USCG strike team would be delayed until the weather pattern changed.

Spill Case 10 occurs within the Intracoastal Waterway, and if contained within one hour, would not reach Minim Creek or the Western Channel, resulting in the contamination of only about 14 km (9 mi) of the waterway.

The oil slick in Case 11 should make landfall within 15 to 30 minutes, contaminating Mosquito Creek before protective measures could be taken. However, crews would have one and one-half to two hours to deploy booms across the Intracoastal Waterway and to position containment devices in the Western Channel. The tide, however, would change in this scenario as additional cleanup and containment equipment were being deployed.

Case 12, a spill of 140,000 barrels of crude oil, would foul both North and South Islands within one hour. Oil would spread extensively into Mud Bay within six hours. Cleanup assistance available after six hours could include Sea Hol Contracting Co. (Charleston), Clean Land and Harbor, Inc. (Wilmington), Industrial Marine Service (Morehead City) and the USCG Strike Team from Elizabeth City. However, effective deployment of much equipment would be precluded by the extreme shallowness of Mud Bay. Protection of Jones Creek, No Man's Friend Creek and Haulover Canal by booms also would not be possible due to the shallow depth.

The oil slick in Case 13 rapidly makes landfall and within three hours spreads along six km (3.8 mi) of the western shore of North Island. Because of the extensive length of shoreline affected by this spill of 2,690 barrels of crude oil, containment and cleanup is expected to exceed local capacity. Cottonpatch Creek, Jones Creek, Sign Creek, Haulover Creek and No Man's Friend Creek again would be too shallow for boom deployment.

Oil from spill Case 14 moves into Winyah Bay within 45 minutes after the spill has occurred, thus precluding booming of Winyah Bay Entrance, which would probably be ineffective anyway because of strong tidal currents and winds. This spill would reverse direction after three hours, during which time it would probably remain uncontained in Ranges C and D of Winyah Bay Channel.

The timing of oil spill Cases 15 and 16, both offshore spills, allows deployment of significant cleanup and containment equipment. Oil in Case 15 first makes landfall on South Island six hours after the spill occurs, reaches Santee Point after 12 hours, and Cape Romain after 24 hours. This gives sufficient time to attempt to boom entrances to bays and rivers in the impacted area to initiate mitigative measures and to begin offshore cleanup operations. Likewise, in Case 16 oil does not reach North Inlet until 12 hours after the spill occurs, allowing sufficient time to mobilize extensive containment equipment. The foregoing discussion of protection of offshore areas assumes almost immediate detection and reporting of the spill.

In summary, it should be pointed out that probably very little containment and cleanup would occur for oil slicks within the major portions of the bay. The use of booms may, if deployed in a timely manner, be helpful in protecting the entranceways of small inlets or tributaries from oil spilled in the bay, or may be helpful in keeping spills within the Sampit River. However, much of the surface area of Winyah Bay, particularly near Mud Bay and the creeks connecting to North Inlet, is too shallow for containment boom operations. Additionally, the deployment of various spill response teams from other areas may not be timely and there is no legal requirement for CRDC to employ response teams to spills originating from vessels in the bay. Finally, as mentioned previously, even containment and cleanup may remove less than 50 percent of the contained surface slick.

3. Cumulative Water Quality Impacts

a. Introduction. The overall water quality of the lower Sampit River and Winyah Bay, as discussed in Sections VI.B.3 and VI.B.4, is classified by the South Carolina Department of Health and Environmental Control as fair (Knox and Turner, 1982), indicating these water bodies are presently somewhat polluted. The existing levels of oxygen demand, metals, organic chemicals and to a certain extent, petroleum hydrocarbons in the sediment and water column can be attributed mostly to discharges of industrial wastewaters from present Georgetown area

industry, or from continual dredging operations for the Intracoastal Waterway and the 8.2 m (27 ft) deep channel project at Georgetown Harbor and Winyah Bay. Further industrial development in this area could serve to reduce the overall level of water quality in the Sampit River and Winyah Bay through increased pollutant loading from wastewater discharge or as a result of increased dredging to accomodate industrial development. Impacts to the water quality in the river and bay should be considered with respect to cumulative impacts from construction and operation of the proposed refinery and from potential additional industrial development in the Georgetown region.

b. Refinery Construction. Construction activities for the refinery and pipeline could increase levels of turbidity, BOD/COD, and other pollutants in the Sampit River and upper Winyah Bay. Turbidity increases due to erosion and runoff from the site would not produce a significant peak impact on turbidity levels, but they may produce a chronic increase over the duration of construction. Dredging activities for pipeline installation in the river bed could produce a significant, short-term increase in turbidity and ammonia levels. Organic humic compounds and nutrients in runoff would tend to increase BOD and eutrophicating conditions in the river during the period of construction. Local wetlands would be impacted by pipeline trenching; while the trenches are open, water and sediment would reach the Sampit River more readily and habitat at and near the trenching would be altered. There could be a slight cumulative impact on the water column and sediments from such construction.

Chemicals such as petroleum hydrocarbons or other pollutants associated with construction activities could reach the water through runoff or airborne deposition; however, they would produce a relatively small increase in ambient pollutant levels compared to industrial discharges presently operating within the area.

c. Refinery Operation. Operation of the proposed refinery would result in introduction of pollutants to the waters of the Sampit River and Winyah Bay through wastewater discharges and potential spills. The wastewater component values discussed below are the best estimates currently obtainable on the proposed refinery's operation. In some cases, however, these values are higher than the estimated USEPA effluent limitations (for comparison, see Table VII.B-10).

Based on the estimated effluent values listed in Table VII.B-7, refinery wastewaters would add about 90 kg of BOD and 325 kg of COD per day to the Sampit River. Compared to the present NPDES limits for BOD (over 6,000 kg/day) and COD (over 56,000 kg/day) from all industries discharging into the Sampit River, the additional impact from refinery discharge for these components would be small.

Discharge of ammonia from the proposed refinery could produce an increase in the ambient level of this potential pollutant, particularly near the outfall. The combined NPDES limit for ammonia presently discharged by other industries is no more than 94 kg/day. Expected discharge from the proposed refinery could add about 93 kg/day of ammonia, an increase of almost 100 percent. Depending upon the wastewater process ultimately chosen, however, the quantity of ammonia discharge may be considerably less than this estimated value.

The oxygen demand imposed by the ammonia in the refinery discharge was included in the overall oxygen demand modeled in the simulations discussed in Section VII.B.a.(1)(d), and very little dissolved oxygen level reduction was imposed.

The oil and grease component of the wastewater effluent also would increase levels of oil and grease in the river and bay. Present industrial discharges of oil and grease into the Sampit River are limited to about 539 kg/day. The refinery wastewaters are expected to add about 117.3 kg/day, which is a 21.8 percent increase over the maximum discharge allowed for the sum of all other industrial sources in the Georgetown area. It should be noted, however, that the NPDES permit would require compliance with the final New Source Performance Standards. Based upon present refinery design plans provided by the applicant, this is estimated to be a maximum of only 30.7 kg/day for oil and grease. If this projected design configuration does not change, the refinery would be limited, therefore, to an increase of 5.7 percent over the maximum discharge allowed for the Georgetown area. It is expected that most oil and grease components of the wastewater would sorb to suspended particles in the vicinity of the outfall and settle into the sediments. This process could create a large cumulative impact to river, and subsequently bay, sediments over time.

Phenols in the refinery wastewater would produce a low cumulative addition to present discharge limitations. It is expected that the refinery effluent would add only one kg/day of phenols to a present discharge limit of 940 kg/day.

The addition of sulfur to the Sampit River, mostly in the form of sulfates from the cooling tower blowdown would represent a comparatively large increase. It is estimated the refinery would add 327.4 kg/day of sulfate. Present NPDES discharge limitations for sulfate from other industries total about 366 kg/day.

The refinery effluent would increase the discharged mass of copper, chromium and zinc by six percent, three percent and 2.5 percent, respectively, over the sum of present NPDES limitations on discharge for these metals to the Sampit River. An overall cumulative increase in the levels of these metals in the sediments also would be expected. Increases in river levels for most other metallic components in the wastewater would be negligible.

Although concentrations of some of these pollutants have been measured in the Sampit River and Winyah Bay, increases in these levels from the additional pollutant quantities expected in the refinery effluent are not easily determined. Modeling of a conservative component discharged into the Sampit River was conducted with results provided in Section VII.B.2.a.(1)(d). The results show that the concentration increases of such a component in the water column would not be great. Dilution would be significant and, after a slight buildup in some areas, concentrations would generally stabilize. The major concern for cumulative effects from process water discharge, therefore, would be for impacts to the sediments, since oil and grease, metals and some other organic compounds would settle and accumulate in these sediments.

If the wastewaters were discharged directly to Turkey or Pennyroyal Creeks it could be expected that the impact on the water column in these waters would be great due to the relatively low volume and expected slow flushing capabilities. Much of the sediment impact associated with the pollutants in the discharge would probably be

found in the creeks themselves, creating less of an impact to the Sampit River. Detailed appraisal of impacts to these water bodies is not possible, however, due to the present paucity of available information on these creeks.

A number of the compounds in the wastewater are toxic, carcinogenic and bioaccumulative, as shown previously in Table VII.B-10. Potential long-term impacts of these compounds are discussed in Section VII.C.

The cumulative impacts from petroleum spills could be significant, depending upon the volume of spill and location. Small spills in the harbor or river would increase the levels of petroleum hydrocarbons in the water column and sediments. This cumulative increase may be enough to create ecological problems that are more significant than the effects of individual spills. Large spills in the river or bay would produce initial levels of petroleum hydrocarbons in the water column that would far exceed quantities introduced by industrial effluent or natural deposition. Large spills also would increase the levels of oils in sediments and

shorelines; if these sources of hydrocarbons are remobilized during ensuing years, these areas would become additional chronic sources of petroleum hydrocarbons in the river or bay.

d. Industrial Development. Potential industrial development for the Georgetown area has been most recently studied by Davis and Floyd, Inc. and Arthur D. Little, Inc. (1983a) and the following discussion is based upon results of that study. Future industrial development along the Sampit River could add additional pollutants, depending upon the type of industry, to those already anticipated with development of a refinery. According to the industrial development study, the types of industries with the highest potential for locating in the vicinity of Georgetown would be forest products industries, textile machinery and chemicals, and shipyard facilities. None of the potential industries were linked to the Georgetown area specifically contingent upon completion of the proposed refinery. However, industries which require large inputs of energy, such as pulp and paper mills, plastic products and chemicals, might consider the presence of the refinery as an added incentive for locating in the Georgetown area.

The International Paper Company plant in Georgetown has begun to orient its energy dependence toward coal. This shift away from oil may tend to reduce the level of activity at the Hess terminal. The proposed refinery then would be the major source of waterborne oil traffic to Georgetown, thus reversing the trend of decreasing oil tanker traffic through Winyah Bay.

While the proposed refinery would not specifically require increased dredging in the Sampit River, Georgetown Harbor and Winyah Bay, further industrial development near Georgetown might be contingent upon increasing the channel depth to 10.7 m (35 ft). A number of the pollutants from the proposed refinery discharge could be expected to accumulate in the sediments of the Sampit River and upper Winyah Bay. Future dredging of the sediments for a greater project depth would create a source of increased pollutants to the river and bay, from both dredge spoil runoff and physical disturbance of sediments causing release of pollutants to the water column.

Future creation of a dredge spoils disposal point near the Harmony Plantation site is planned. Runoff from such a disposal site could increase the level of suspended particles in the Sampit River near a proposed refinery outfall. This could result in an increase in the potential for sorption and deposition of refinery wastewater pollutants in the Sampit River near Pennyroyal Creek. The cumulative impact on the sediments in this area would be greater than for further downstream in the river or for locations in the bay, because tracer studies and mathematical modeling have demonstrated that refinery pollutants can accumulate in this vicinity and that flushing capability would be less than for downstream areas.

e. Summary. Although construction and operation of the refinery would degrade water quality in the Sampit River and Winyah Bay, project effects should not be sufficient to violate any water quality standards. The primary impact of construction would be a temporary increase in water turbidity from runoff and excavation in the Sampit River. The primary impact of the operation of the refinery would be the degradation of water quality due to the pollutants contained in the wastewater discharge. A significant increase of pollutants in sediments near the [illegible]

anticipated. Most of the oil and grease components, for example, would probably be retained in sediments near the outfall. Dispersion and dilution of this wastewater within the Sampit River and Winyah Bay should reduce most component concentrations in the water column downstream of the outfall as indicated by the results of modeling shown in Table VII.B-11.

Oil spills within the study area could impose significant immediate and long-term impacts. Cumulative impacts from the spills would include deposition of oil in the sediments with possible chronic release of pollutants to the water over a long period of time. Any portion of the Sampit River and Winyah Bay or any of its tributaries or inlets could potentially be damaged by an oil spill, depending upon specific circumstances. Depending upon the size of the spill, significant portions of the bay or tributaries could retain oil in the sediments for many years.

Although not specifically tied to development of the proposed refinery, further industrial development in Georgetown may be positively influenced by the presence of the refinery. Any such future development could contribute to water quality degradation, but compliance with water quality permits should preclude unacceptable impacts.

4. Unavoidable Adverse Water Quality Impacts

Impacts to water quality from plant and pipeline construction activities could be substantially reduced if all available mitigative measures were to be implemented. The actual extent of reduction of impact, however, would be dependent upon variables that are difficult to quantify at the present stage of refinery design planning. Some levels of impact would be unavoidable, however, particularly with respect to increased turbidity and BOD loading from dredging activities for installation of the subaqueous pipelines.

As long as oil is transported through the Winyah Bay system, the potential for oil spills will exist. A large spill has a very low probability of occurrence and may never occur during the lifetime of this proposed refinery. Small spills have a much greater probability of occurrence and may be considered unavoidable over a long time. The impacts of spills are addressed in Section VII.B.2.b.

Runoff and small unavoidable handling losses are chronic pollutant sources which would continue as long as the refinery would be in operation. Although runoff sources could be substantially limited by good housekeeping procedures, small handling losses would always occur. The water quality impacts relevant to these losses are discussed in Section VII.B.2.a.(3).

C. ENVIRONMENTAL CONSEQUENCES ON FISH AND WILDLIFE RESOURCES

1. FROM PLANT AND PIPELINE CONSTRUCTION

a. Existing Conditions at the Harmony Plantation Plant Site

Wildlife habitat on the proposed refinery site is characterized as a homogeneous longleaf pine-turkey oak association. As is typical in this area of the South Carolina coastal plain there are expansive areas of this vegetative type contiguous with, and in the vicinity of, the proposed refinery site.

Typically, this vegetative association is considered to be relatively low quality wildlife habitat in terms of species diversity and population numbers. To meet such life requirements as feeding, mating, nesting, resting and sanctuary it is necessary that most birds, mammals and some reptiles have access to diversified habitats which are created through the interspersion of different plant and water communities. Since the habitat on this site is relatively homogeneous there is insufficient interspersion amongst community types to support abundant and diverse wildlife populations. Another major factor which detracts from the quality of the habitat at the site is the lack of a well-developed and actively growing understory and subcanopy.

The site probably does support a moderate to low density of breeding birds consisting primarily of the pine warbler, brown-headed nuthatch, mourning dove, and bobwhite quail. Other bird species which frequent this vegetative type to meet their various life requirements include the screech owl, Bachman's sparrow, Eastern wood peewee, Southern crested flycatcher, red-bellied woodpecker, Carolina chickadee, summer tanager, blue jay, tufted titmouse, cardinal, sharp-shinned hawk and Eastern turkey.

Mammals found in this longleaf pine-turkey oak association and adjacent forested communities can be lumped into three major groups: 1) herbivores, 2) omnivores, and 3) predators. The largest of these is the herbivore group, with individual species ranging in size from small rodents to the white-tailed deer. The white-tailed deer has extremely diverse habitat requirements and thus will be found at some time in all the communities in the vicinity of the project. Vegetation on this site is relatively sparse and low in diversity of desirable browse and therefore is not of high value to deer. Other less conspicuous herbivorous mammals that occur on this site include the Eastern wood rat, cotton mouse and cottontail rabbit. These mammals provide a valuable function in this relatively open ecosystem as prey for hawks, owls, foxes and other predacious animals.

The most common omnivorous mammals present on this site are the raccoon and the opossum. These species utilize this site primarily for feeding on nuts, seeds, fruits, insects, small rodents, and birds.

The most common carnivorous mammals on this site include the long-tailed weasel, gray fox, red fox, and bobcat. Of the two fox species, the gray fox is the most common. This can probably be attributed to its more diverse food habits than that of the red fox.

Amphibians and reptiles are present in this vegetative type but are concentrated primarily along the margins of moist areas where conditions are most conducive to their existence. Some representative species include the pine woods

treefrog, gopher tortoise, Southern black racer, corn snake, pine snake, and Eastern diamondback rattlesnake.

Endangered wildlife species that can be expected to occur in the general project area include: bald eagle, red-cockaded woodpecker, wood stork, and American alligator. Onsite evaluation of the proposed refinery site revealed that none of these species are present. The habitat provided in this vegetative community is not suitable for feeding, nesting or reproduction of any of the above species.

b. **Effects of Plant Construction**

Development of the sandy, longleaf pine-turkey oak association site described above as a refinery facility will result in the conversion of approximately 100 acres and almost total loss of the wildlife habitat qualities it now possesses. This vegetative type is abundant in coastal South Carolina and since it possesses no habitat qualities that are unique or in short supply, its loss will not jeopardize the existence of any wildlife species. Mobile species that now utilize this site for all or part of their life needs will probably move to adjacent habitats as construction begins. The less mobile species or those with extremely small home ranges will probably perish.

Some temporary impacts to the Sampit River biota are anticipated from increases in turbidity due to alteration of upland drainage patterns and increases in erosion caused by wind and water runoff from large areas cleared for construction. Sampit River biota may also experience adverse effects from chemical and hydrocarbon pollutants which may enter the Sampit River with runoff from spillage at the construction site.

c. **Effects of Pipeline Construction**

Pipeline construction will result in the temporary disturbance of upland and aquatic communities along its alignment. Although definitive plans are lacking, it is assumed, as with other pipelines, that the pipeline and access corridors would be maintained in a cleared condition. Since these corridors represent just a small portion of available upland habitats and may still be used by wildlife in the cleared condition, no significant impact on wildlife is anticipated. Pipeline burial under the Sampit River is expected to result in short-term impacts to the benthic community through physical disruption and perhaps short-term disturbances to other components of the aquatic community from construction generated turbidity. Since the substrate overlaying the pipeline following burial will not be different from that currently existing in the proposed alignment, it is anticipated that benthic recolonization will be rapid and no change in community structure will result. Therefore, no long-term, significant impacts are anticipated from physical pipeline construction.

2. EFFECTS OF PLANT OPERATION

a. Effects of Petroleum on Estuarine Organisms

1. Introduction

Plant operation is most likely to affect fish and wildlife resources through chronic, accidental or catastrophic release of crude oil or refined petroleum products into the aquatic environment. In order to present a logical framework from which to assess the impact of these discharges, the following literature review is presented emphasizing acute and chronic effects of petroleum upon groups of organisms which are likely to be most severely affected in Winyah Bay. With few exceptions, the bulk of the following text is extracted (with permission) directly from Allen et al. (1982).

Crude oil contains many different components which vary according to molecular size and type. Degradation processes for crude oil and various chemically dispersed oils have been described in the National Academy of Science's report on petroleum in the marine environment (NAS, 1975) and the Proceedings of the 1981 Oil Spill Conference (American Petroleum Institute, 1981). Oil released to the aquatic environment immediately undergoes many alterations. Initially, spilled oils spread rapidly into thin layers, forming an oil slick. Hydrocarbons less than 15 Carbon molecules long evaporate and are volatilized from the surface waters within 10 days (Kreider, 1971). Other hydrocarbons are dissolved or form particles, many of which settle into the sediments. Hydrocarbons also form tarballs, and some are removed by photochemical oxidation. Petroleum products are also subject to microbial degradation and uptake by organisms.

Impacts of hydrocarbons on estuarine organisms are influenced by many factors, including amount of oil released, type of oil, solubility of the oil, and reactions with dispersants. Dispersants used to treat oil spills, or dispersant/oil combinations, may be more biologically damaging than the hydrocarbons which were initially released. Currents, circulation, morphometry of the area, and meteorological conditions can also affect toxicity. Highly turbulent zones such as sandy beaches are usually less sensitive to oil spills than estuaries and salt marshes (Gundlach and Hayes, 1978). High current and wind velocities in the open sea during storm conditions may disperse oils more quickly, thereby reducing their direct impact. However, in enclosed areas, such conditions may spread the oil over large, more sensitive areas (e.g., salt marsh and estuarine communities). Turbulent factors also increase the suspension of particulate materials to which oil adheres. Greater concentrations of oil are carried to bottom sediments when turbidity is greatest. Timing of the impact is also important because spills during the warmer months of the year are more likely to affect sensitive larval stages and reproductively active adults.

Several mechanisms have been described through which plants and animals are exposed to oil. Direct contact is the most obvious method and is often responsible for decreased growth, fouling of feeding and swimming structures, or death. Hydrocarbons can be absorbed through the body walls of many organisms. Other mechanisms include ingestion of oiled particles and food chain transfer through ingestion of contaminated prey items. Impacts vary depending on mode of contact, duration, exposure, and type of oil or oil fraction. Effects may be categorized as being acute or chronic. Acute effects are generally immediate and severe and may include death or debilitation. Acute exposure to aromatics during the first few days after an oil spill may be responsible for many of the

reported fish and bird kills and population declines of plankton and larvae. Chronic effects generally result from continued exposure to refinery effluents, repeated small spills, or resuspension of contaminated benthic sediments and may be lethal or sublethal.

2. Effects on particular organism groups

a) Phytoplankton

The effects of petroleum hydrocarbons on phytoplankton have been previously reviewed (Corner, 1978; Johnson, 1977; Snow, undated; Vandermeulen and Ahern, 1976). Effects vary depending on the sensitivity of the species and the concentration of oil to which they are exposed (Dunstan et al., 1975; Mironov, 1968, 1972; Mironov and Lanskaya, 1966; Pulich et al., 1974; Thomas et al., 1980). Species sensitivity is governed by many factors, especially physiological condition (Stoll and Guillard, 1974). The severity of an oil spill also varies seasonally and is generally greater during spring or summer months (Gordon and Prouse, 1972; Fontaine et al., 1975). Other factors, including water solubility (Currier, 1951; Kauss et al., 1973) and reactions with dispersants affect hydrocarbon toxicity (Batelle, 1973; Scott et al., 1979).

Heavy concentrations of crude oil have long been known to inhibit phytoplankton growth (Galtsoff et al., 1935). More recent laboratory studies have adequately demonstrated the detrimental effects of petroleum hydrocarbons on both marine phytoplankton (Mironov and Lanskaya, 1969; Mommaerts-Billet, 1973; Pulich et al., 1974) and freshwater species (Kauss and Hutchinson, 1975; Soho et al., 1975a,b). Extensive damages following actual oil spills have also been described (Diaz-Piferrer, 1962; Clark et al., 1973).

Specific effects of oil exposure include inhibition of cell division and subsequent reductions in cell number (Mironov and Lanskaya, 1966), inhibition of photosynthesis (Gordon and Prouse, 1972), reduction of CO_2 exchange (Shiels et al., 1973), damage to the plasma membrane (Van Overbeck and Blondeau, 1954), inhibition of oxidative phosphorylation (Vandermeulen and Ahern, 1976), modification of DNA and RNA polymerization (Davavin et al., 1975) and elimination of bicarbonate uptake (Kauss et al., 1973).

Low concentrations of oil stimulate growth and photosynthesis in some species (Snow and Scott, 1975; Shiels et al., 1973). Some hydrocarbon fractions inhibit photosynthesis at all concentrations (Parsons et al., 1976) and phytoplankton populations may never recover after initial exposure to hydrocarbons (Lee et al., 1977). Generally, the lag phase in population growth is lengthened and the exponential phase is depressed. Recovery of phytoplankton populations after initial inhibition has been related to large evaporative losses of hydrocarbons (Vandermeulen and Ahern, 1976; Lacaze, 1974; Mahoney and Haskin, 1980).

b) Macrophytes

The effects of oil on macrophytes have been reviewed by Johnson (1977) and Snow (undated). Several studies have examined the impacts of acute oil spills on marshes (Stebbings, 1968; Burns and Teal, 1971; Lytle, 1975; Macko et al., 1981; Bender et al., 1977; Hershner and Moore, 1977) and prolonged marsh grass exposure to refinery effluents (Baker, 1976a,b; Dicks, 1976). Results generally

indicate that marsh grasses can survive a single mild exposure to oil, but multiple doses may be fatal.

Responses of macrophytes to hydrocarbon exposure are varied. Effects may be severe, and large macrophyte communities may virtually disappear (Ranwell, 1968; Anonymous, 1953). Reported increases in phytoplankton and macrophyte populations after exposure may be due largely to the decimation of herbivore populations (North et al., 1965; Miller et al., 1978; Johansson et al., 1980). Seed germination may be almost completely inhibited after exposure to crude oil (Baker, 1971). Stands of Spartina alterniflora exposed to multiple doses of oil experience serious lethal effects and many sublethal effects, including delayed development, increased density, reduced mean weight per stem, and suppression of cohort production (Hershner and Lake, 1980).

c) **Zooplankton**

Contact with hydrocarbons can result in a variety of effects in zooplankton which differ from species to species. Some forms may simply rid themselves of the hydrocarbons (depuration) with relatively little negative effect; others may metabolize it to less toxic forms and store it in lipids or other compounds (Sanborn and Malins, 1977), whence it can be passed up the food chain; in other instances sublethal effects such as reduced offspring number or life span can be induced; finally, contact with hydrocarbons or dispersants can have direct lethal effects.

Numerous studies (e.g., Wells, undated; NAS, 1975) have documented direct death in zooplankton populations from contact with hydrocarbons, both in the field and in the laboratory. On the other hand, Conover (1971) found relatively little effect of oil on copepods and showed that ingestion of oil could result in transport of up to 20% of the oil from the surface to the bottom in the form of fecal pellets. Other studies have shown that zooplankton ingest oil in particles of various sizes (Wells, undated), that feeding rates or particle selection can be modified by the presence of various sizes of oil particles (Berman and Heinle, 1980), and that rate of depuration of oil may depend upon whether it was ingested (slower) or taken up through the body wall (faster; Corner et al., 1976). The effect in any given survey or experiment depends on types of oil or oil fraction, concentration, time of exposure, environmental conditions (temperature, salinity, etc.) and species of zooplankton.

Sublethal effects are the most difficult to document and are often hard to recognize. In addition, the impact of various sublethal effects on zooplankton populations is difficult to predict because of the lack of understanding of zooplankton biology in general. Documented sublethal effects of exposure to oil include changes in rate of feeding, reduction of activity levels (e.g., immobilization or narcotization), behavioral changes (e.g., loss of orientation, loss of ability to select substrates, loss of sensory abilities), physiological effects (e.g., reduced respiration/excretion rates), and life history effects (e.g., reduced clutch size, clutches per lifetime, offspring viability, or adult life span). The variety of sublethal effects on zooplankton are reviewed in Wells (undated).

Studies performed on zooplankton (usually in boreal or temperate waters) have shown that most zooplankton as individuals are very sensitive to dispersed and dissolved petroleum (NAS, 1975; Wells, undated). This sensitivity must be considered in light of the great diversity of zooplankton and the variety of oil

types and fractions they might contact. Considerable work has been performed on some groups, especially protozoans, coelenterates, ctenophores, polychaetes, molluscs, crustaceans (especially barnacles, copepods, amphipods, mysids, shrimps and crabs), echinoderms, and fishes. Other groups largely have been ignored, such as foraminiferans and radiolarians, cladocerans, ostracods, cumaceans, isopods, larvaceans (appendicularians), and chaetognaths. In most cases, the groups mentioned above have not been studied in the southeastern United States, except for the Gulf coast of Louisiana and Texas. Although results vary, some forms (i.e., ctenophores and decapod larvae) appear to be particularly sensitive to hydrocarbons. Decapod larvae are more susceptible during molting or in the early stages of development. Some studies have shown that barnacle larvae are fairly sensitive (Wells, undated), but others (e.g., Lee and Nicol, 1977) have shown that they are more resistant than most copepods. Sensitivity of molluscs and echinoderms varies, but early cleavage stages are usually more sensitive than eggs or adults (Wells, undated).

Few toxicity studies have been performed on species which are found in the study area; in a recent review of the literature on zooplankton from Cape Hatteras to Cape Canaveral, Alden (1977) cited no studies of oil effects on southeastern plankton. Lee and Nicol (1977) studied effects of No. 2 crude oil on coastal/oceanic zooplankton in the Gulf of Mexico and concluded that although coastal zooplankton were more tolerant of the water-soluble fractions (WSF's) than the oceanic forms, they still suffered negative effects ranging from reduced survival to behavioral aberrations. They attributed differences between coastal and oceanic zooplankton to the fact that there were larger numbers of particularly resistant forms (barnacle nauplii, polychaete larvae) in the coastal plankton and speculated that holoplanktonic forms were more sensitive.

Studies of Eurytemora affinis (reviewed by Dawson, 1979), a species which occurs in upper Winyah Bay, showed that ingestion rates were reduced by 38% in concentrations of oil which might be found under a spill (0.52 mg/l, or parts per million, ppm). Exposures to more than 1 mg/l resulted in narcotization and death. Numerous life history effects were also recorded, including reduction in adult life span, clutch size, and number of eggs/lifetime when E. affinis were exposed to WSF's or naphthalene. Exposure to concentrations of hydrocarbons for more than 4 hours (as under a spill) could have significant negative sublethal effects on E. affinis life history parameters.

Numerous studies have been performed on species of Acartia, including A. tonsa. Berman and Heinle (1980) found that concentrations of fuel oil of 70 ug/l (parts per billion, ppb) did not affect feeding, but concentrations of 250 ug/l resulted in several different types of feeding modifications, from reduced feeding rate to changes in the sizes of particles filtered. Hebert and Poulet (1980) reported that exposure to Venezuelan crude oil rapidly and significantly reduced growth and survival of Acartia hudsonica and that feeding behavior and particle size selection were also affected. Ott (1980) found that egg production was significantly depressed by exposure to 50 ug/l naphthalene and that young females were more sensitive than older females. In addition, a higher percentage of infertile eggs were produced during early exposures to naphthalene.

Studies on locally-occurring crabs generally bear out the results of investigations in other areas: early larval stages are more sensitive. Laughlin et al. (1978), working with Rhithropanopeus harrisii (a species which occurs in the fresher waters of Winyah Bay), found that all larval stages were negatively affected by exposure to sublethal concentrations of

water-soluble fractions of No. 2 fuel oil. Earlier stages were more sensitive, but later stages, including megalopae and adults, appeared to recover from chronic sublethal exposure. The major effect of chronic exposure on these crabs may be reduction in population size or viability due to reduced recruitment into the adult population. Cucci and Epifanio (1979) found negative effects in larvae of the mud crab Eurypanopeus depressus when exposed to various concentrations of WSF of Kuwait crude oil; as with previous investigators, they found more effects in earlier stages but also a greater incidence of morphologically abnormal megalopae after exposure.

In summary, effects of exposure to various types and concentrations of hydrocarbons appear to have similar impacts on southeastern zooplankton as on plankton studied in other parts of the world. These may range from immediate mortality to relatively innocuous and temporary behavioral modifications. The degree of impact can vary considerably depending upon exposure, species, life stage of the organism and environmental conditions.

d) **Benthic and Intertidal Organisms**

Many studies have shown that petroleum products cause a variety of lethal and sublethal effects in marine and estuarine organisms, including benthic or epibenthic forms (reviewed in NAS, 1975; Percy, undated). One of the important variables governing the impact of oil is habitat type; oil on a high-energy coastline may be rapidly removed, whereas if it impinges on low-energy environments considerable time may be required to disperse it. Gundlach and Hayes (1978) have developed a vulnerability index which indicates that inter- and subtidal habitats in estuaries like Winyah Bay/North Inlet are among the most difficult to clean and, once inundated with oil, take the longest time to return to normal conditions (Sanders et al., 1980). This is largely because estuarine inter- and subtidal habitats contain fine, porous mud-sand substrates which readily incorporate and retain oils under the low-energy hydrographic regime in which they occur.

Intertidal organisms are especially susceptible to physical damage (coating, smothering, fouling) by oil because of their exposed position (Straughan, 1972). Fine particulate material is coated with oil and incorporated into inter- and subtidal sediments, from which toxic hydrocarbon fractions can leach for long periods of time. Many authors believe that intertidal organisms are actually less susceptible to oil inundation than subtidal animals because of their inherent resistance to physical stresses (Newell, 1970), but direct negative effects (e.g., reduced growth or metabolism, behavioral aberrations, mortality) from spills have been demonstrated for most benthic taxa (George, 1970; Rossi and Anderson, 1978; Thomas, 1978) both inter- and subtidally.
Most benthic organisms rapidly take up hydrocarbon fractions, which cause various physiological, behavioral, and metabolic effects; many of these organisms quickly depurate hydrocarbons when put into clean water (Lee, 1977). There is usually rapid uptake and loss to a stable level in which some hydrocarbon fraction remains in the organisms in a detoxified or metabolized form (e.g., Anderson, 1975). Such stored hydrocarbons can be passed up the food chain, reaching even humans in the case of commercially important species like oysters, clams, shrimps and crabs.

Sublethal effects on benthic organisms are numerous and include reduced or increased respiration rates (Gilfillan, 1973; Percy, 1977), formation of neoplastic lesions (Albeau-Fernet and Laur, 1970; Yevich and Barszcz, 1976),

narcosis or reduced muscular activity (e.g., Corner et al., 1976), and reduction of chemosensory ability (Atema et al., 1973; Pearson and Olla, 1979). Modification of growth rate, molting ability or frequency, and reproductive processes are especially important sublethal effects which have major implications for populations of benthic and intertidal invertebrates. The vast literature on these subjects reports considerable differences in the degree to which exposure to petroleum causes sublethal effects among taxa (Percy, undated), but nearly all species studied to date are affected to some degree. In contrast, at the community level, Spies and Davis (1979) and Davies and Spies (1980) found a deposit feeding, infaunal community that had apparently adapted to a chronic petroleum problem at a natural oil seep in the Santa Barbara Channel.

Larvae and juveniles of benthic organisms are more severely affected by contact with petroleum than adults. Larvae of many commercially important species (e.g., crabs, oysters, clams) as well as non-commercial forms (e.g., polychaetes, barnacles) have been shown to be injured in various ways by petroleum fractions (Caldwell et al., 1977; Byrne and Calder, 1977), and death of larvae or of newly settled or hatched juveniles (e.g., Edwards, 1980; Woodin et al., 1972) has frequently been recorded. Although Tatem et al. (1978) found that young penaeid shrimp were more resistant than older shrimp, the opposite is true for most benthic invertebrates. One of the major effects of oil spills on benthic/intertidal organisms is the reduction of population size or viability by loss of recruits.

In summary, benthic and intertidal organisms suffer negative impacts from acute exposure to hydrocarbons and from long-term chronic exposure. Although the effects vary between species and habitats, they are generally negative and may lead to significant changes in the quality of the ecosystem or the value of the resources which may be taken from the system.

e) **Fish**

Impacts of oil spills on fish populations are variable and range from little or no effect to large fish kills (Gooding, 1968; Cerame-Vivas, 1968). In creeks receiving chronic discharges of oil field wastes, 5-16 times fewer gamefish were harvested and yields of blue crabs and forage fish showed similar declines (Spears, 1971). These adverse impacts were thought to extend into the bay which received the creek input. Petroleum-based hydrocarbons are magnified in the food web (Lu and Metcalf, 1975; NAS, 1975; Koons et al., 1976), and therefore may pose a more serious hazard to higher trophic level organisms such as fish. Effects of oil exposure depend upon many environmental conditions, including salinity and temperature (Linden et al., 1979). Effects of chronic oil exposure may be most severe to fish species which are year-round residents and are frequently in contact with bottom sediments, such as flounders and eels (Fletcher et al., 1981), or feed on bottom organisms, such as the endangered short-nosed sturgeon.

Primary stress responses include increases in osmolality, concentrations of plasma glucose (hyperglycemia) and cholesterol (Thomas et al., 1980), and respiratory (or opercular) rates (Thomas and Rice, 1975; Brocksen and Bailey, 1973). Other possible effects include decreased growth rates (Hawkes, 1977; McCain et al., 1978), increased liver to body weight ratios (Yarbrough et al., 1976), fin rot (Minchew and Yarbrough, 1977), severe damage to gill epithelial tissue (Nuwayhid and Davies, 1980; Clark et al., 1974; Blanton and Robinson,

1973), induction of benzo(a)pyrene monooxygenase activity (Kurelec et al., 1977; Payne and Penrose, 1975; Payne, 1976), and histological damage to chemoreceptors (Gardner et al., 1973). Oil exposure also may result in the tainting of fish flesh (Mackie et al., 1972; Blumer et al., 1970; Shipton et al., 1970).

Fish larvae are very susceptible to oil pollution and treatment with dispersants (Wilson, 1977), although species differ as to their sensitivity (Kuhnold, 1970). Larvae of an economically important species, the spotted seatrout (Cynoscion regalis), exposed to sublethal concentrations of water-soluble fractions of fuel oil as low as 0.1 ppm, displayed a general decrease in total body length and critical distance, and the percentage of larvae with unpigmented eyes increased with increased oil concentration (Johnson et al., 1979). Other reported larval effects include disruption of phototactic and feeding behavior (Wilson, 1970). Fry show avoidance reactions to hydrocarbons, which may disrupt migrations (Rice, 1973).

Fish embryos exposed to oil experienced decreased hatching; damage to liver, kidney, lens and epithelial tissues; mitochondrial damage (Ernst et al., 1977; Cameron and Smith, 1980), and decreased survival (Linden, 1978). Buoyant fish eggs tend to congregate at the water surface and are especially susceptible to the effects of toxins. Effects of treatment with oil dispersants include abnormalities in cell division and differentiation and reductions in heart rate, eye pigmentation, growth rate, and hatching success (Wilson, 1976).

f) **Birds**

Of the groups of vertebrate animals that are exposed to oil pollution, birds are probably the most adversely affected (see reviews by NAS, 1975; Brown, undated). Diving birds in particular are severely affected by oil spills. This group includes the familiar pelicans, coots, cormorants, loons, grebes, mergansers, and the highly gregarious diving ducks. For example, nearly half of the Tay estuary population of diving sea ducks was lost in 1968 as a result of the Tank Duchess oil spill (Greenwood and Keddie, 1968). The size of the oil spill usually gives no indication of the magnitude of the damage. More than 5,500 birds were killed by the leakage of only about 27 tons of oil from the barge Irving Whale along the coast of Newfoundland (Brown et al., 1973). It has been estimated that only 5 to 15% of those birds killed by oil actually wash onto shores, therefore estimated death tolls are probably severe underestimates.

One of the most serious effects on birds is the breakdown of feather structure, which results in loss of waterproofing and insulation (Hartung, 1967). This condition leads to severe thermal stress and may often result in the death of the afflicted bird.

Oil is ingested by birds through preening activity (Hartung, 1965) and feeding on contaminated prey organisms. Ingested oil has been reported to cause heterotrophy of the nasal gland, liver, adrenals and changes in the morphology of intestinal tissues in some birds (Miller et al., 1978b). Other possible effects include physiological stress (Butler et al., 1979; Crocker et al., 1974, 1975), inhibition of nutrient transfer (Miller et al., 1978a,b), reduction of growth (Miller et al., 1978a) and narcotization (Southward, 1978). Crude oil ingested by female birds causes reproductive success to decline by decreasing egg production, hatchability, and egg shell thickness (Hartung, 1965; Holmes et al., 1978; Grau et al., 1977) and by reducing survival of offspring produced by these birds (Vangilder and Peterle, 1980).

Oil may easily be transferred to the surface of eggs by oiled parents during incubation. Experimentally applied oil resulted in the death of embryos of mallards, eiders, herons, gulls and terns (Albers, 1977; Coon et al., 1979; Hartung, 1965; Szaro and Albers, 1977; White et al., 1979). When female mallards were smeared with only 5 ml of mineral oil, the eggs did not hatch.

In summary, bird populations may be severely affected by oil spills. Adverse impacts are likely to be most serious in areas where birds are highly concentrated, especially breeding and feeding grounds and in waters adjacent to major migratory flyways.

g) **Mammals**

Very little is known about the potential impacts of an oil spill on mammals. Although the effect of oil on muskrats has been documented (McEwan et al., 1974), most of the existing information regarding effects on mammals pertains to groups which occur outside of the study area, such as seals (refer to Geraci and Smith, 1976; Smiley, undated, for lists of pertinent references).

Specific effects may include damage to appendages (Warner, 1969; Davis and Anderson, 1976), eye irritation (Geraci and Smith, 1977), reduction of insulating properties of fur (Kooyman et al., 1977) and the formation of mild kidney lesions (Smith and Geraci, 1975).

3. **Summary**

Marine organisms are exposed to hydrocarbons through four basic mechanisms: direct contact, uptake of dissolved fractions through the body wall, ingestion of contaminated prey organisms, and direct ingestion of oil or oil-laden particles. Hydrocarbons can cause acute (direct) or sublethal effects in organisms, which range from immediate death to reduced growth and reproduction. Toxicity of hydrocarbons may vary for a number of reasons. Direct contact produces the most immediate and damaging effects, but ingestion or uptake also causes lethal and sublethal damage. Impacts vary according to the amount and types of oils involved, and highly refined fractions are frequently most toxic. Dispersants and dispersant/oil combinations sometimes result in more significant adverse impacts than the oil itself. Populations of highly sensitive species may be totally destroyed, whereas other species may suffer less dramatic sublethal effects, and species of low sensitivity may actually experience sudden dramatic population increases (Sanders et al., 1980).

Susceptibility of organisms varies with habit and stage of life cycle. Heavily oiled marsh grasses, such as Spartina alterniflora, will die, and less-heavily contaminated grasses will experience sublethal effects, including decreased growth and inhibition of seed germination. Buoyant eggs and surface-dwelling organisms will be affected by direct contact, while animals and plants in the middle part of the water column will be most severely affected by the water-soluble fractions and by contact with or ingestion of oiled particles. Benthic and intertidal organisms will be affected by smothering and direct contact with or ingestion of oiled sediments. Larger, more motile animals (fishes, shrimps, and crabs) may or may not be able to avoid direct contact but will still be affected by ingestion of hydrocarbon-containing organisms lower on the food chain or absorption of water-soluble fractions through their body walls.

Effects of oil on aquatic organisms often vary seasonally and are generally more severe during the warmer months when larval and planktonic forms are abundant and when reproductive activity is high. Many commercially important species may be affected, particularly in the larval (decapods, shrimps, fish) or the newly-settled juvenile (clams, oysters) stages. Soft-bodied forms (e.g., ctenophores, jellyfish, and appendicularians) are poorly studied but appear to be especially sensitive to hydrocarbon pollution.

Birds are abundant in highly productive estuarine systems and are probably the most severely affected vertebrate group; oil spills may result in almost total destruction of local populations. Spills adjacent to breeding, feeding and rafting areas result in an unusually high number of casualties and may severely affect population levels for many years. Temporary visitors may also experience adverse effects, especially when oil spills occur in areas adjacent to major flyways of birds or migration routes of aquatic organisms (e.g., marine turtles, anadromous and catadromous fishes).

The most extensive long-term study of the effects of an oil spill in an estuarine habitat (Sanders et al., 1980) showed that negative impacts, such as physiological and behavioral disorders and instability in density, diversity, and species richness, persisted as long as seven years after the initial spill. There is no reason to believe that similar habitats along the east coast of the United States would behave differently or would be less affected by an oil spill.

Estuarine areas subject to chronic low-level hydrocarbon inputs, such as those receiving refinery effluents, experience high mortalities of marsh grasses near the discharge and changes of species composition and abundance of both flora and fauna in receiving waters. Areas near the effluent source suffer the most severe impacts, and pollutants accumulate over time, particularly in systems with low circulation properties. Effects are less likely to be acute, but sublethal effects may be widespread. Reduced catches of commercially important species (fish, shrimp, and crabs) and forage species are likely to occur in adjacent bays receiving the effluent.

b. Impacts of Chronic Discharges

Chronic discharges from the proposed CRDC refinery would consist of an effluent composed of oil-free sewer water, cooling-tower blowdown water, and process water to be discharged either to Turkey Creek or the Sampit River; sanitary wastewaters to be discharged to the Georgetown water treatment plant; stormwater runoff and small unavoidable handling losses, and air emissions. Estimated volumes, pollutant concentrations, and water and air quality impacts are discussed in previous sections of this document. Since the sanitary wastewater would be discharged to a publicly-owned waste treatment facility and not from the refinery itself, following sections address only the proposed wastewater discharge, stormwater runoff and small unavoidable handling losses, and air emissions.

1. Wastewater discharge

Estimated process water components, regulatory standards and criteria, and pollutant fate characterization associated with the proposed refinery wastewater discharge are presented in Table VII.B-10. As proposed by the applicant, the

treated refinery wastewater would contain quantities of oil and grease, heavy metals, and other toxic pollutants that would exceed various regulatory standards and/or criteria for maintaining water quality standards and viable aquatic populations. However, as noted on page VII.B-20, the most restrictive of the three effluent limitations shown in Table VII.G-9 is the dominating regulatory control for each refinery effluent constituent. The NPDES permit would therefore require compliance with the NSPS, which require a higher level of treatment than that proposed by the applicant. For example, reference to Table VII.B-10 shows that the NSPS limitation for oil and grease is 30.7 kg/day which is only 26.2 percent of the estimated daily discharge based on information provided by the applicant.

Field and laboratory data, as presented in earlier sections, have demonstrated the acute lethal toxicity and long-term sublethal toxicity of hydrocarbons to aquatic organisms. Because of the wide range of compounds included in the oil and grease category, it is impossible to establish meaningful aquatic life criteria without specifying the component involved. Also, due to lack of definitive data regarding the chronic toxicity of hydrocarbon fractions, no aquatic life criteria have been specifically established for hydrocarbons expected in the proposed CRDC refinery wastewater.

Although there are no specific criteria for "safe" levels of oil and grease in the aquatic environment, data have shown that marine larvae, the most susceptible organisms to hydrocarbons, appear to be intolerant of petroleum pollutants, particularly the water soluble fractions (WSF's), at concentrations as low as 0.10 ppm (USEPA, 1976). Many of these WSF's are polycyclic aromatic hydrocarbons (PAH's) which are listed as priority pollutants by the USEPA. Three species of crab larvae were found to have 48-hour mean tolerance limits of 4 to 10 ppm oil and grease (Caldwell et al., 1977; Katz, 1973; Cucci and Epifanio, 1979). After 6 days exposure to 1.0 ppm WSF's, sand goby exhibited only a 50 percent survival rate (Berge et al., 1983). These data indicate that the refinery effluent would be acutely toxic to most aquatic organisms if sufficiently concentrated.

In order to project the expected water quality impacts of the proposed wastewater discharge on the receiving water body (assumed to be the Sampit River), two simulations using the RECEIV water quality model and 1.0 mg/l of a conservative pollutant were run. As a one-dimensional model, the RECEIV model assumes complete mixing vertically and horizontally across the river. As stated on page VII.B-30, the model is not suitable for simulations in Winyah Bay nor is it reliable for simulations of non-conservative substances including most of the constituents of the refinery effluent.

In addition to expected high dilution factors derived from the RECEIV model, a large portion of the discharged oil and grease, heavy metals, and other organic toxicants are predicted to precipitate fairly rapidly and accumulate in sediments near the outfall. Direct mortalities due to the acute toxicity of the wastewater would thus generally be limited to organisms in the immediate vicinity of the outfall. (However, due to the low water volume and expected slow flushing capabilities of Turkey and Pennyroyal creeks, direct mortalities due to the acute toxicity of the proposed effluent would be much greater should the outfall be located in one of these creeks.)

Of generally greater concern than the acute toxic effects of the wastewater (provided rapid dispersion and dilution of the wastewater as predicted by the RECEIV model occur) are the long-term effects of chronic exposure to sublethal concentrations of oil and grease, heavy metals, and other toxic pollutants expected in the refinery wastewater. Long-term, sublethal effects of oil pollution, which can result from direct exposure to pollutants in the sediments or water column or through uptake of contaminated food organisms, include interferences with cellular and physiological processes such as feeding and reproduction. While these effects do not result in immediate death of organisms, they do endanger the continued viability of populations of the affected organisms by shortening individual life spans, reducing reproductive success, and making organisms less resistant to normal environmental stresses.

Disruptions of such behavior (feeding, reproduction, etc.) apparently can result from petroleum concentrations as low as 10 to 100 ppb (USEPA, 1976). Mironov (1967, 1970) reported that 10 ppb oil produced deformed and inactive flatfish larvae and 1 to 1000 ppb inhibited or delayed cellular division in algae. It is therefore expected that similar sublethal effects would occur in the Sampit River and Winyah Bay if petroleum concentrations reach the levels cited above. These effects would be evidenced by lower population levels, reduced value of spawning and nursery habitat, and possible elimination of more sensitive species from the Sampit River and ultimately Winyah Bay itself.

The high propensity of oil and grease for adsorption and precipitation and the resultant accumulation in sediments where concentrations of various hydrocarbon fractions may reach or exceed toxic thresholds of many benthic organisms greatly increase the likelihood that significant adverse effects would result from the proposed chronic discharge of refinery wastewaters. Armstrong et al. (1979) found wastewater from an oil separator facility in Texas contained 0.0019 ppm total naphthalenes while the sediment under the outfall contained 28 ppm total naphthalenes (the projected level of naphthalene in the CRDC effluent is 0.001 ppm). The bay bottom was nearly devoid of organisms within 15 meters of the outfall and populations were severely depressed up to a 150 meter radius (17.45 acres) around the outfall.

Similar sediment accumulations, losses of benthic biota near the outfall due to acute toxicity, and occurrence of severely depressed benthic populations outside the immediate area of the outfall due to chronic exposure to sublethal levels of hydrocarbon contaminants would be expected to result from discharge of the proposed refinery wastewaters. Once incorporated into Sampit River sediments, these hydrocarbons could serve as a chronic source of pollutants long after the proposed discharge had ceased. This loss of benthic productivity would diminish the Sampit River's contribution as a food source of many of the bay's juvenile and adult fishes.

Hydrocarbons accumulated in Sampit River sediments would be taken up and in some cases bioaccumulated by benthic invertebrates. These contaminants would then be transferred to bottom-feeding fish and waterfowl (Tarshis and Rattner, 1982) that consume contaminated benthic organisms. Documented sublethal effects of hydrocarbons on bottom-feeding fish include high tumor rates correlated with high body levels of PAH's in bullhead catfish (Baumann et al., 1982) and significant changes in three neurotransmitter chemicals in channel catfish exposed to benzo(a)pyrene and naphthalene (Fingerman and Short, 1983). Aromatic hydrocarbons have also been shown to stress liver function in mallard ducks (Patton and Dieter, 1980).

Oil and grease from the CRDC refinery effluent could also adversely affect fish and wildlife resources in the Sampit River and Winyah Bay by inhibiting primary production and altering species composition and diversity of planktonic communities. Some hydrocarbon fractions inhibit photosynthesis at all concentrations (Parsons et al., 1976); photosynthesis by phytoplankton has been shown to be depressed in chronically polluted coastal waters (Gordon and Prouse, 1972). Chronic exposure to petroleum has been found to decrease species diversity in both phytoplankton (Hohn, 1959) and zooplankton (Odum et al., 1963) communities. Phytoplankton communities may become dominated by nuisance species such as the filamentous blue-green algae Oscillatoria, known to produce abundant growths in refinery waste lagoons (McKee, 1956). Additionally, incorporation of oil into sediments inhibits the normal uptake and release of soluble nutrients, metals, and inorganic substances to the water column -- availability of these soluble products is essential to photosynthesizing plants

(Applied Biology, Inc., 1983). Lytle (1975) found reduced productivity of marsh plants exposed to oil: 96.9 grams in an oil-contaminated pond vs. 173.2 grams from a control pond (weight of 30 day's growth). Reduced primary productivity would ultimately be evidenced in reduced secondary productivity of the Sampit River/Winyah Bay system. Changes in species composition of Sampit River planktonic communities would be expected, with more sensitive species and forms possibly being eliminated. Since the marine finfish and crustacean egg and larvae component of the zooplankton community appear to be the most sensitive to hydrocarbon pollution, the value of the Sampit River as a nursery area for blue crab, shrimp and finfish would be diminished.

As stated in Section VII.B, the refinery effluent would increase the discharged mass of copper, chromium, and zinc by six percent, three percent and 2.5 percent, respectively, over the sum of present NPDES limitations on discharge for these metals to the Sampit River. An overall cumulative increase in the levels of these metals in the sediments also would be expected. Increases in river levels for most other metallic components in the wastewater would be negligible.

These metals are very toxic, persistent and are bioaccumulative to the extent that concentrations found in fish may greatly exceed concentrations in the environment. Although any increase in heavy metals is undesirable, the increments attributed to the refinery are not significant.

The proposed refinery wastewater would also contain low levels of various polychlorinated biphenyls (PCB's), compounds which are toxic to aquatic organisms in parts per billion or less, do not easily biodegrade, are highly bioaccumulative and carcinogenic, and which proliferate throughout aquatic (and terrestrial) ecosystems, concentrating in upper-trophic-level consumer species. However as noted in Section VII.B, PCB's are excluded from regulation under the refining point source category because they were not detected in refinery effluents by Section 304 (h) analytical methods or other state-of-the-art methods.

Particularly sensitive to very low levels of PCB's is the copepod *Acartia tonsa*, a vital link in the Winyah Bay food web that accounted for more than 60 percent of all zooplankton collected in the bay by Allen et al. (1982) during the second year of their bay study (see page VI.D-15). The mean tolerance limit of adult *Acartia* to Aroclor 1016, a PCB listed by the proposed refinery developer as an expected wastewater contaminant, was found to be 50 parts per trillion (Zillioux, E. J., E. F. Corcoran, M. R. Reeve, and L. L. Farmer. 1975. Uptake, concentration, and biological effects of several organochlorine substances through a simple marine food chain. Final report to the Environmental Protection Agency, EPA Grant #R-800352, University of Miami, Miami, Florida). Earlier life forms are known to be considerably more sensitive in general to toxic pollutants such as PCB's but PCB tolerance limits for early *Acartia* life forms were not investigated in the above-referenced study.

Any significant reduction in the bay's *Acartia tonsa* population would disrupt food chains of many if not most of the bay's fish species. Subsequent fish population declines could be expected, although the degree of decline would depend upon the availability of adequate populations of other zooplankters and the ability of the bay's fishes to adapt to new or less preferred food organisms.

Because of the highly bioaccumulative nature of PCB's, the discharge of any level of this contaminant is cause for concern. Fish can bioaccumulate PCB's up to 61,000 times the surrounding water concentrations directly from the water column or by consumption of contaminated food organisms. Oysters can accumulate this toxic pollutant by a factor 100,000 times ambient water concentrations (USEPA 1976). However in view of the failure noted in Section VII.B to even detect PCB's in the effluent from BPT (best practical control technology currently available) treatment systems, it is considered unlikely that PCB's in the refinery effluent would have a significant impact on aquatic resources.

While the adverse impacts of the proposed CRDC chronic wastewater discharge would be most severe in the Sampit River (assuming the outfall is located in the river), these impacts would not be confined to the river. Though water quality modelling results (Table VII.B-11) and a subjective evaluation of pollutant retention in the water column (Table VII.B-12) indicate that direct transport of many wastewater contaminants into the bay via the water column would be expected to be limited, movement of contaminated sediments from the Sampit River to Winyah Bay is expected to occur via sediment transport mechanisms and dredging/disposal activities.

Hydrocarbons, heavy metals, and other refinery wastewater contaminants would also be expected to reach Winyah Bay through the many complex food chains that exist in this estuarine complex. Proliferation of refinery wastewater contaminants throughout these food chains would occur as free-swimming organisms that utilize waters throughout the Winyah Bay system are directly exposed to contaminants in the Sampit River via the water column or consumption of contaminated food organisms in the river (particularly benthic invertebrates). Eventually, aquatic biota throughout Winyah Bay would experience to some as yet unquantified (and currently unquantifiable) degree the effects of long-term, chronic exposure to sublethal levels of hydrocarbons, heavy metals, and other wastewater contaminants discharged from the proposed CDRC refinery.

In summary, the discharge of refinery wastewater would result in the further degradation of water and sediment quality in the Sampit River. Direct exposure to and the uptake of wastewater contaminants from either the water column or from sediments could be acutely toxic near the outfall to some species. Chronic toxic effects would extend an undetermined distance from the outfall with severity decreasing with distance. The high propensity of most of these pollutants for absorption and precipitation would result in their accumulation in Sampit River sediments where they would act as a chronic source of hydrocarbons, heavy metals, and other inorganic and organic pollutants for an indefinite time.

Movement of refinery wastewater contaminants into Winyah Bay would occur through various pathways, including water column transport, sediment transport mechanisms, dredging and disposal activites, and transfer through the food chain. Once these contaminants are incorporated in Winyah Bay sediments and food chains, long-term, chronic impacts similar to those expected in the Sampit River could occur. Whether or not the concentration of these contaminants would be sufficient to cause noticeable effects in Winyah Bay can not be determined. The exposure to refinery wastewater could have the following effects on fish and wildlife resources in the lower Sampit River. The dilution of the effluent in Winyah Bay makes it unlikely that these impacts would be great enough to be detectable in Winyah Bay.

1) Reduction of benthic diversity and biomass.
2) Decrease in primary productivity of adjacent marshes.
3) Changes in phytoplankton composition.
4) Depressed photosynthesis by phytoplankton.
5) Reduction of zooplankton diversity and biomass.
6) Degradation of nursery habitat for shrimp, crabs and finfish.
7) Reduction of recreational and commercial catches.
8) Degradation of habitat for shorebirds, wading birds and waterfowl.

2. Runoff and small unavoidable handling losses

Runoff and small unavoidable handling losses from both refinery and pier operations have the potential for causing small-scale yet chronic pollution problems. As stated in the water quality section, it is estimated that 250,000 gpd of oil-contaminated stormwater would be generated at the refinery site. The API Separator proposed to treat this oil-contaminated runoff is a gravity-separation process which, for refinery wastewaters, can achieve at best an effluent oil concentration of 50 ppm (Manning and Snider, 1983). The amount of flow entering an API Separator during and following a storm varies over time, resulting in less-than-optimal conditions for gravity-separation treatment. Thus, potentially lethal concentrations of oil and grease may be introduced into the Sampit River from the refinery site during storm events. Neither small, unavoidable handling losses at the refinery site nor runoff and handling losses at the pier have been quantified.

Basically, these types of chronic discharges would have impacts similar to those associated with the refinery effluent, although lethal toxicity effects may be greater than those of the effluent. Oxygen-demanding substances, suspended solids, oil and grease, and heavy metals would be contained in these discharges. Heavy metals and hydrocarbons would be of particular concern due to their toxicity and ability to accumulate in sediments and bioaccumulate in aquatic organisms.

Refined oils are often associated with runoff and small, unavoidable handling losses. These are often more toxic than crude, unrefined oils and would have a more immediate and direct impact on aquatic organisms: fish kills are often associated with small releases of refined oil products into the aquatic system.

Areas that would be affected by these chronic discharges include the mid- and lower Sampit River and upper Winyah Bay; Turkey and Pennyroyal creeks would likely be affected as well. Depending upon the fate of sediments contaminated by these discharges, the impacts associated with runoff and small, unavoidable handling losses from refinery and pier operations could extend into the Winyah Bay system. The cumulative increases of hydrocarbon levels in the water column and sediments due to these small chronic discharges would be expected to create ecological problems that are more significant than the effects of the individual discharges themselves.

c. **Impacts of Oil Spills**

1. **Impacts associated with any spill in or affecting the Winyah Bay area**

Occurrence of any of the hypothetic crude-oil spill scenarios described in the water quality section except cases 3 and 4 would be expected to have severe negative impacts on most of the flora and fauna that occur in the Winyah Bay system. The degree and magnitude of negative impacts would vary somewhat among the scenarios presented due to the actual extent of aquatic habitat affected; however, the impacts of any oil spill affecting the Winyah Bay system would be expected to include the following:

1) Death or reduced vitality of vegetation in direct contact with oil.

2) Conversion of marsh to mudflats where vegetation is completely destroyed.

3) Reduction in abundance and diversity of plankton, invertebrates, and finfish populations due to sublethal effects of various petroleum fractions.

4) Undesirable changes in species composition of plankton and invertebrates.

5) Death of plankton, invertebrates and fish due to the acute toxicity of various petroleum fractions.

6) Reduction in recreational and commercial catches of shrimp, crabs and finfish.

7) Objectional taste and odor of seafood taken in affected area.

8) Death of birds coming in direct contact with oil.

9) Reduction in shorebird, wading bird, waterfowl, and raptor populations due to reproductive failure.

10. Contamination of private and state-owned waterfowl impoundments.

11. Adverse effects on furbearers inhabitating affected marshes such as mink, otter and raccoon.

12. Long-term reduction in the existing productivity and associated natural, scientific, and economic values of the aquatic resources of Winyah Bay due to the persistence of heavy metals and hydrocarbons in sediments and the continuing sublethal effects on all trophic levels as these sediments are resuspended and reintroduced into the foodchain.

2. Impacts associated with the seventeen presented hypothetical oil spill scenarios

a) Introduction

Seventeen oil spill scenarios presented in Section VII.B.2.6.(2) consist of twelve less than total loss cases (less than 140,000 barrels); four total loss cases (spills of 140,000 barrels), and loss of 60,000 barrels from the tank farm associated with the proposed refinery located at the Harmony Plantation site. Five of the cases involve refined products; ten involve crude oil, and two involve both refined and crude oils. Hypothetical spill circumstances (type and volume of spill, location, time of year, river discharge, tidal stage, and wind conditions) are given in Table VII.B-14.

The Winyah Bay Oil Spill Trajectory Model used to simulate the lateral displacement of a floating oil spill in Winyah Bay and model limitations are discussed in Section VII.B.2.b.(2)(c). The following section will attempt to quantify, to the degree possible, the fish and wildlife impacts that would be associated with the occurrence of each of the 17 spill cases as described in Section VII.B.2.b.(2)(c) and not necessarily as depicted in Figures VII.B-3 through VII.B-18 which in some cases do not correspond exactly with the possible extent of spill coverge as discussed in the text. Also, while Section VII.B.2.b.(6) addresses the feasibility and potential effectiveness of containment/cleanup operation, the following impact assessment takes these into consideration only to the extent that such operations are included in the presentation of spill case descriptions.

As stated numerous times through this document, the impacts of any given oil spill are dependent on a myriad of factors. Impacts on fish and wildlife resources are largely dependent on the spill location and the time of occurrence of the spill. Therefore, in order to facilitate an evaluation and qualitative discussion of impacts for the 17 hypothetical spill cases, the spills are grouped according to location of primary impact area. Specific impacts associated with each spill are based on location and season of occurrence.

Based on work by Allen et al. (1984), Winyah Bay is divided into three regions: the upper bay, middle bay, and lower bay. The major characteristic used to distinguish these areas is salinity which affects the distributional patterns of both chemical and biological components in Winyah Bay. The upper bay is dominated by freshwater input from rivers. The middle bay is the mixing zone, and the lower bay is dominated by saltwater input from the ocean.

The upper bay, that region above the Belle Isle-Frazier's Point constriction, is characterized by low tidal amplitude. The predominant water flow is toward the ocean, especially following major storms when maximum freshwater inflow occurs. The middle bay region extends from the Belle Isle-Frazier's Point constriction to the Shell Banks near the narrow ocean end. This region is physically the most complex and a diversity of habitats is present. Tidal amplitude and current velocities are greatest in the ocean-dominated lower bay region which extends from the narrows at Shell Banks to the ocean.

Time of year that a spill occurs influences the subsequent impacts of that spill, as biological activities vary seasonally. Species and life forms present in the bay vary from month to month; therefore, the specific fish and wildlife impacts associated with any given spill will differ to some degree. Table VII.C-3 lists by season the particularly significant biological activities with respect to oil spills; Table VII.C-4 shows anticipated temporal presence of larval forms of commercially and recreationally important species in Winyah Bay. While Table VII.C-4 shows a period of relatively low biological activity in the bay in regard to the species listed (October, November, and December), Table VII.C-3 clearly indicates that a spill occurring during any month of the year could have significant impacts on the bay's fish and wildlife resources.

b) **Upper bay impacts (cases 1 through 9 and 17)**

Based on the oil spill trajectory model, primary impacts of spill cases 1 through 9 and 17 would occur within the Sampit River and upper Winyah Bay (above the Belle Isle-Frazier's Point constriction). These spill cases vary considerably in terms of spill volumes and areal extent of slick coverage; thus, the magnitude of expected impacts vary as well. Differences in toxic and behavioral characteristics between crude and refined products as well as differences in time of occurrence also dictate the severity of adverse impacts associated with each of these nine spills. Primary impact areas, potential marsh acreages affected, and major species and/or life stages likely to be affected by each of these spills are presented in Table VII.C-5.

Although the magnitude and areal extent of impacts associated with each of these nine spills vary considerably as indicated in Table VII.C-5, certain general impacts are common to all nine scenarios. These general impacts, discussed in detail below, are based in large part on the results of work just completed by Allen et al. (1984) in Winyah Bay.

Table VII.C-3. Significant seasonal biological activities in the Winyah Bay system with regard to oil spills.

WINTER (December - February)

- American shad juveniles utilize bay as nursery in December, mature adults migrate to ocean in February.
- Atlantic and endangered shortnose sturgeon juveniles over-winter in mid-bay to jetties area.
- Waterfowl have highest seasonal abundance in impoundments and open waters of the bay.

SPRING (March - May)

- Juvenile hickory shad descend from rivers into bay.
- Mature sturgeon migrate offshore.
- Spotted seatrout spawn in lower estuarine reaches and off beaches.
- Loggerhead turtles nesting on beaches at bay mouth.
- Highest numbers of birds nesting at Pumpkinseed Island rookery.
- Highest seasonal movement of larvae of commercially and recreationally important species into the estuary.

SUMMER (June - August)

- Hickory shad juveniles utilize bay as nursery.
- American shad juveniles utilize upper bay (above Hwy. 17 bridge) as nursery.
- Atlantic and endangered shortnose sturgeon over-summer in upper bay.
- Loggerhead turtles nesting on beaches at bay mouth.
- Highest seasonal abundance of brown shrimp.
- Highest seasonal phytoplankton activity.
- Highest seasonal densities of zooplankton and highest seasonal zooplankton constituency by larvae of crustaceans, polychaetes, mollusks and fishes.

FALL (September - November)

- Mature hickory shad migrate offshore.
- Juvenile sturgeon migrate from lower river system to bay.
- Weakfish and mullet migrate offshore to spawn.
- Highest seasonal abundance of pink and white shrimp, blue crabs, star drum, hogchoker.

Table VII.C-4. Anticipated temporal presence of larval forms of commercially and recreationally important species in the estuary.

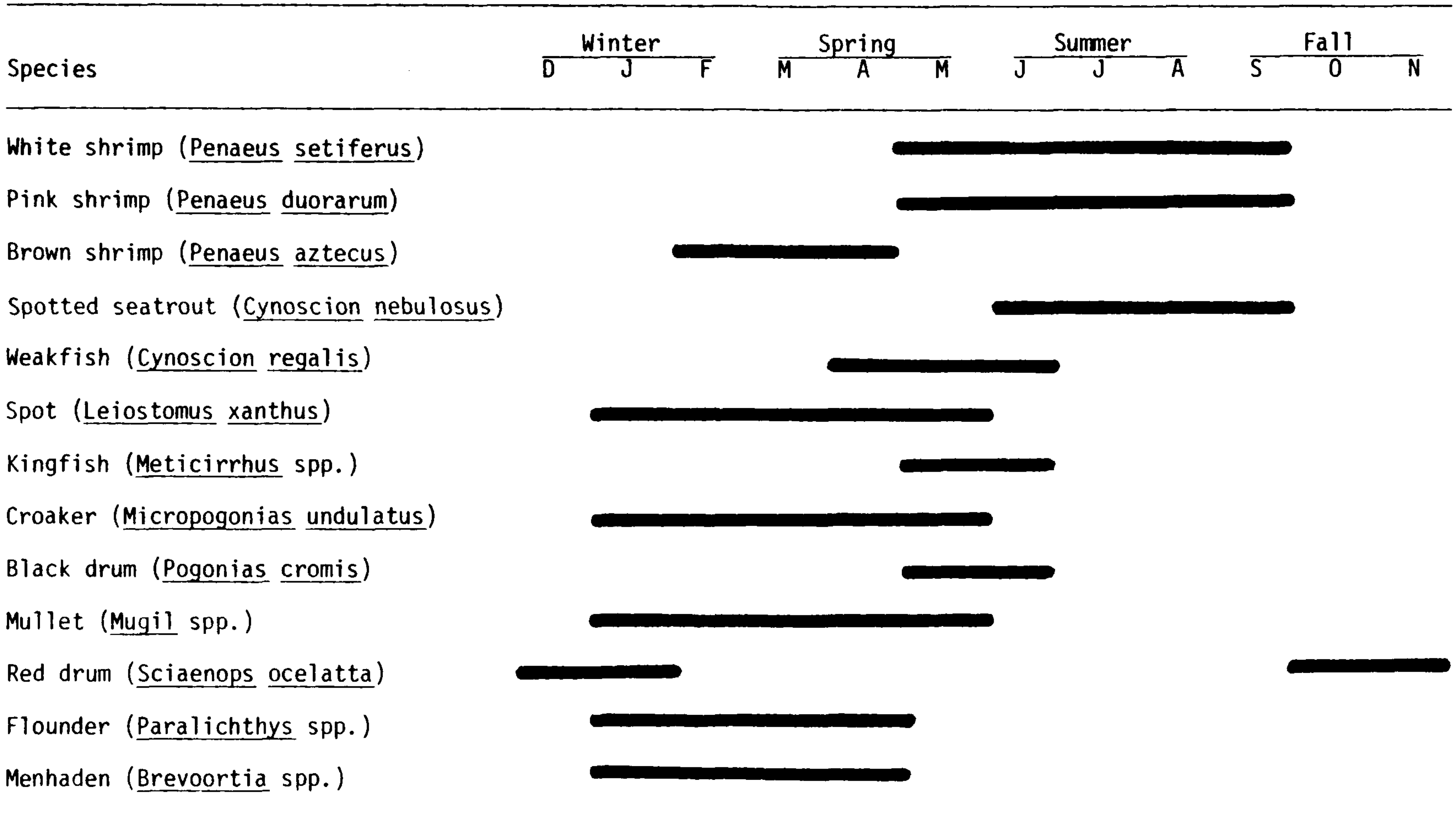

Table VII.C-5. Impacted areas, marsh acreages, biological activities and special considerations associated with hypothetical spills affecting upper Winyah Bay.

Spill case	Barrels and product spilled	Month	Primary[1]/secondary[2] impact areas	Wetlands acreage potentially affected[3] (primary/primary + secondary)	Significant biological activity/species affected	Special considerations
1	667 refined	August	6.7 mi. of Waccamaw River/upper Winyah Bay	780+[4]/NQ	American shad juveniles; Atlantic and endangered shortnose sturgeon; brown shrimp; highest seasonal phytoplankton activity; highest larval densities of blue crab, white and pink shrimp, spotted seatrout	Contamination of Samworth Game Management Area
2	112 crude and 112 refined (jet fuel)	March	Sampit River above US 17 bridge to harbor and upper bay/tide and wind could translocate either upstream or downstream of spill site	152[5]/NQ[6]	Anadromous fish spawning runs; juvenile hickory shad descending from rivers into bay; highest seasonal movement of larvae, including brown shrimp, spot, croaker, mullet, flounder, and menhaden; bald eagles nesting and feeding	Extreme toxicity of refined products; accumulation of persistent hydrocarbons and heavy metals in lower river sediments; increased ambient pollutant levels in water and sediments
3	9.5 crude	May	Sampit River at Pier 31 and upper Winyah Bay/upstream Sampit River	152/NQ	Juvenile hickory shad descending rivers to bay; highest seasonal movement of larvae, including white and pink shrimp, weakfish, spot, kingfish, croaker, black drum, and mullet	Cumulative impacts of several small spills which would increase ambient levels of hydrocarbons and heavy metals in the sediments and water column; this cumulative increase would create ecological problems more significant than the effects of the spills alone
4	6.5 refined	January	Lower Sampit River, upper bay to Rabbit and Hare islands/eastern bay shoreline near Bellfield Plantation	304[7]/315	American shad juveniles; anadromous fish runs beginning; highest seasonal abundance of waterfowl; larval spot, croaker, mullet, red drum, flounder, and menhaden; bald eagles nesting and feeding	Same as for spill case 3
5	1,218 crude	March	Sampit River from Pier 31 to Pennyroyal Creek (3.7 miles)/lower Sampit River and upper Winyah Bay	810/944[8]	See spill case 2	Possible contamination of waterfowl impoundment at Friendfield Plantation; introduction of persistent, toxic pollutants to middle/upper Sampit River system

Table VII.C-5. (Continued)

Spill case	Barrels and product spilled	Month	Primary[1]/secondary[2] impact areas	Wetlands acreage potentially affected[3] (primary/primary + secondary)	Significant biological activity/species affected	Special considerations
6	42,000 crude	July	Lower Sampit River and upper Winyah Bay including Rabbit and Hare islands and Waccamaw Neck from Horse Island to Baruch Institute/entire upper bay and Waccamaw River to US 17 bridge (due to large volume of oil, minor fouling may be detectable throughout the bay)	534/1302[9] (potentially the entire shoreline of Winyah Bay)	American shad juveniles; Atlantic and endangered shortnose sturgeon; brown shrimp; highest seasonal phytoplankton activity; highest larval densities, including blue crab, white and pink shrimp, and spotted seatrout; high numbers of shorebirds and wading birds; colonial bird nests on Pumpkinseed Islands	Possible fouling of Mud Bay and Pumpkinseed Island rookery; fouling of Baruch Institute wetlands
7	2,277 crude	October	Winyah Bay shoreline from Sampit Point to south of Belle Isle Gardens in vicinity of Western Channel/other portions of Winyah Bay (undetermined locations)	481/NQ	Mature hickory shad migrating offshore; juvenile sturgeon moving from lower river system to bay; weakfish and mullet migrating offshore to spawn; highest seasonal abundance of pink and white shrimp, blue crab, star drum, and hogchoker; red drum larvae	Accumulation and persistence of toxic pollutants in marsh sediments; possible contamination of middle bay region due to transport of polluted sediments
8	17,000 refined	October	Winyah Bay shoreline northward from Sampit Point to 1.9 mi. up Pee Dee River (with wind, 8.5 mi. upriver)/Pee Dee, Black and Waccamaw rivers to extent of tidal excursion (unknown point on Pee Dee and Black, but at least as far as Mile 16 on Pee Dee; possibly to Little River Inlet via AIWW on Waccamaw)	1008[10]/NQ	Same as spill case 7	Potential for extensive contamination of riverine systems; possible contamination as far north as Little River Inlet; contamination of Samworth Game Management area.

Table VII.C-5. (Continued)

Spill case	Barrels and product spilled	Month	Primary[1]/secondary[2] impact areas	Wetlands acreage potentially affected[3] (primary/primary + secondary)	Significant biological activity/species affected	Special considerations
9	140,000 crude and 17,000 refined	June	Eastern and western shorelines of Winyah Bay above Frazier's Point; Sampit River to Pennyroyal Creek, and Pee Dee and Waccamaw rivers to extent of tidal excursion/Belle Isle Gardens, Esterville Plantation, the AIWW, western shore of Marsh Islands, Cat Island, and North and South islands (with ebbing tide, oil is likely to move into AIWW and Mosquito Creek as far as tidal movement allows; Mud Bay and Pumpkinseed Island may receive minor fouling)	3905[11]/8706[12]	American shad juveniles; Atlantic and shortnose sturgeon; brown shrimp; highest seasonal phytoplankton activity; highest larval densities, including blue crab, pink and white shrimp, spotted seatrout, weakfish, kingfish, and black drum; high numbers of shorebirds and wading birds; colonial bird nesting on Pumpkinseed Island	Extensive and persistent contamination of riverine system to the extent of tidal excursions; contamination of nursery and over-summering habitats of anadromous fishes, including the endangered shortnose sturgeon. Also extensive, persistent contamination of Winyah Bay, including Esterville Plantation, Yawkey Wildlife Center, and Baruch Institute holdings; possible fouling of Mud Bay and Pumpkinseed Island rookery during period of high bird use for feeding and nesting activities. A spill of this magnitude within Winyah Bay would threaten the continued viability of this entire estuarine ecosystem
17	60,000 refined	July	Turkey and Pennyroyal creeks; both shorelines of Sampit River from Pennyroyal Creek to bay; southerly portion of harbor; Sampit Point; Rabbit and Hare islands/entire upper bay from Horse Island to Baruch Institute and Waccamaw River to US 17 Bridge	1977[13]	See spill case 6	Accumulation and persistence of toxics in marsh and river bottom sediments; Turkey and Pennyroyal creeks may never recover if spill enters these small creeks; fouling of Baruch Institute wetlands; possible fouling of Samworth GMA; extensive acute mortalities due to highly toxic nature of refined products.

[1]Primary impact area is that area projected to be impacted prior to a tidal change following the spill (as discussed in Sections VII.B.2.b.(2) and (4).

[2]Secondary impact area is that area projected to be directly impacted following a tidal change (as discussed in Sections VII.B.2.b.(2) and (4).

[3]Acreage was planimetered from wetlands map (Figure VI.D-1) and generally includes the entire wetland area along the shoreline affected by the spill.

Table VII.C-5. (Concluded)

[4]This is the acreage from the wetlands map which extends approximately 1.5 miles above the U.S. 17 bridge; thousands of acres of wetlands would be affected by a spill reaching 6.7 miles above the bridge. The extent of fouling along the Winyah Bay shoreline following a tidal change was not determined, thus the wetlands potentially impacted are not quantified (NQ).

[5]Includes shoreline wetlands from the vicinity of the proposed pipelines (18 acres), the harbor (12 acres), and the northern (15 acres) and southern (107 acres) shorelines of the river to the bay.

[6]Not quantified; actual extent of spill impact area undetermined.

[7]Represents spill as depicted in Figure VII.B-6 to point of landfall on Rabbit and Hare islands (includes 19 and 15 acres along southern and northern shorelines of Sampit River and 270 acres on Rabbit and Hare islands). On flood tide, 11 acres of eastern Winyah Bay shoreline would be directly affected. The 315 acres represents affected shorelines as shown in Figure VII.B-6.

[8]Includes 12, 15, 107 acres in the harbor and along the north and south shorelines of the Sampit River (to the bay), respectively.

[9]Acreage bordering the slick 4 and 11 hours, respectively, following the spill. The 1,309 acres corresponds to affected shorelines as shown in Figure VII.B-8.

[10]This represents the wetland acreage along the western bay shoreline from Sampit Point to the U.S. 17 bridge (94 acres); 693 and 221 acres, respectively, long the western and eastern shorelines of the Pee Dee River to approximately river mile 2.0. Several thousands of additional wetland acres would be affected with slick movement 8.5 miles upriver. Slick penetration to the extent of tidal excursion along the Pee Dee, Black, and Waccamaw rivers would foul many thousands of acres of freshwater marshes as well as forested wetlands (bottomland hardwoods and cypress-tupelo wetlands). However, actual acreage potentially affected is not quantified because of limited extent of wetlands map and uncertainty in the spill scenario regarding actual extent of oil penetration.

[11]Acreage planimetered from wetlands map is much less than would be expected from spill description, as map extends approximately 2 miles up the Waccamaw and Pee Dee rivers while the extent of tidal excursion is much greater (the salt water wedge alone may reach mile 16 on the Pee Dee). The 3,905 acres border the spill area as depicted in Figure VII.B-11, except that the Sampit River was planimetered to Pennyroyal Creek.

[12]Includes entire western/southern bay shoreline from Belle Isle Gardens to South Island and Mother Norton Shoals (to extent shown on wetlands map), North Island from bay entrance to South Jones Creek, Marsh Islands, and unnamed island adjacent to Western Channel (4,801 acres) as well as 3,905-acre primary impact area.

[13]Represents wetlands of Turkey and Pennyroyal creeks and the Sampit River from the juncture of Pennyroyal Creek to Winyah Bay (includes 19 and 15 acres along the southern and northern shorelines of the Sampit River juncture with the bay) and 270 acres on Rabbit and Hare islands. Greater acreages would be affected if the spill is carried further up the Sampit River by tidal fluctuations. Tidal movements in Winyah Bay could also extend the area of impact associated with this major spill.

Oil spills in the Sampit River/upper Winyah Bay area would result in some decreases in nutrient concentrations. Benthic communities would experience drastic declines, causing decreased nutrient availability as remineralization rates decline. Such effects would be most noticeable in the Sampit River which has a much smaller watershed and thus receives less phosphorus and nitrogen from agricultural runoff than either the Waccamaw or Pee Dee rivers.

Planktonic species would be unable to avoid oil slicks or soluble hydrocarbon fractions in the water column following a spill. Both direct mortality and sublethal effects would occur. Primary production in the water column would probably increase initially, as oily wastes act as a nutrient source and as many herbivores are killed. Restructuring of the phytoplankton community would be expected as highly sensitive species are destroyed and other less sensitive, often nuisance, species experience dramatic increases.

The most severe effects upon primary producers would be the destruction of aquatic macrophyte communities (marshes) which receive direct oiling. Mortality of marsh plants could result in large areas being denuded of plants. Subsequent erosion and/or changes in sediment characteristics could prevent re-establishment of marsh vegetation and once-productive marshes would become unvegetated tidal flats. The loss of these marsh areas would have long-lasting effects not only in terms of lost primary productivity but also due to the loss of vital nursery areas for many larval/juvenile fishes and invertebrates.

Since most zooplankters are extremely sensitive to hydrocarbon pollution, species diversity in this community would decrease following a spill. According to Allen et al. (1984), total zooplankton numbers and biomass in the upper regions of the bay may decrease as much as 70 to 80 percent. Only a few species would dominate the community. Amphipod populations, which were found to be most abundant in this upper portion of the bay, would probably be decimated in the spill area as they are very intolerant of hydrocarbon pollutants.

Crustacean larvae (especially shrimp larvae) are generally very petroleum-sensitive and would likely experience dramatic decreases in abundance. Crab zoea, important constituents in the upper Sampit River, would also be adversely affected. Occurrence of a spill during the months when blue crab, white shrimp, and/or brown shrimp larvae are at maximum population levels would result in direct mortalities which would be evidenced by lower population levels the following year and perhaps much longer. Mortality of crab larvae, decapod shrimp, amphipods, and mysids would also affect higher trophic level fishes for which these larvae are important food organisms.

Damage to larval and juvenile fishes would be greatest in the shore zone and old rice field ditch habitats where these life forms are known to be most abundant. The large spills would result in massive die-offs of fishery stocks, especially if the spills coincide with maximum larvae/juvenile population densities or species use (as shown in Tables VII.C-3 and VII.C-4). Resident populations of adult fishes, particularly bottom-associated species such as the flounder and endangered shortnose sturgeon, could experience significant mortality losses. The direct (acute and sublethal toxicity) and indirect (loss of nursery habitat, food items, etc.) impacts of such spills would inevitably result in a decline in commercial and recreational catches. Tainting of fish flesh from direct exposure to hydrocarbons or ingestion of contaminated food items could become a serious problem resulting in severe financial hardships for local fishermen.

Shorebirds, wading birds, waterfowl, and predatory birds would experience

negative impacts from a spill in the upper bay. Actual number of birds present at the particular time of a spill would result in greater or lesser individual impacts to each particular species and to future populations of these species utilizing the Winyah Bay area. However, those individuals present in the bay at the time of spill occurrence would be expected to suffer potentially large losses due to direct mortality from contact with the spilled oil and sublethal effects from ingested oil. Subsequent years' populations may be severely reduced for some time due to sublethal effects and loss of or reduced quality of feeding and nesting habitat.

Comparisons of seasonally significant biological activities in the bay (Tables VII.C-3 and VII.C-4) with individual spill data in Table VII.C-5 give an indication of the probable significance of each of the hypothetic spill occurrences in relation to overall bay productivity. The relatively low volumes associated with spill cases 2, 3, and 4 may be expected to result in the least significant impacts of these ten lower Sampit/upper bay spills on overall bay productivity. However, if such smaller spills are repeated, the cumulative impacts could be much greater than the impact of a single spill.

Spill cases 1 and 5 would have drastic impacts on the riverine systems of the Waccamaw and Sampit rivers, respectively; introduction of oil into Winyah Bay is possible from either of these spills. Spill case 17 would be devastating to Turkey and Pennyroyal creeks and the Sampit River; this spill could also result in significant impacts to the upper bay and Waccamaw River. Spill cases 7 and 8 would have immediate detrimental impacts on significant portions of the upper bay and possibly the rivers (especially spill case 8 which could affect the Pee Dee and Black rivers as far as 16 and 13 miles upstream, respectively, and the Waccamaw River conceivably as far as Little River Inlet), while spill cases 6 and 9 would result in maximum impacts on the upper bay. Occurrence of either of the latter two spills would result in significant resource losses that would be reflected in major declines in overall bay productivity. The occurrence of spill case 9 could also directly affect the middle bay. With a tidal change, oil above Frazier's Point would move down Winyah Bay where it is likely to foul Belle Isle Gardens, Esterville Plantation, the Atlantic Intracoastal Waterway (AIWW), the western shore of Marsh Islands, Cat Island, and North and South islands. With the ebbing tide, oil is likely to move into the AIWW and Mosquito Creek as far as tidal movement would permit. Mud Bay, including the northern shore of Pumpkinseed Island, may receive minor fouling.

Emulsification of these spilled products in which relatively stable oil-in-water emulsions are formed would greatly increase the amount of oil in the water column. In addition to increasing direct aquatic organism exposure to oil via the water column, emulsification would also increase significantly the area that would be impacted by these spills.

Based on the expected impacts to sediments presented in Section VII.B.2.b.(4), each of these spill occurrences would result in flocculation, with oil settling to the bottom and incorporating in sediments. A portion of the oil could also be incorporated into bottom sediments by direct dissolution where it would persist for considerable periods of time, probably years.

The inclosed nature of Winyah Bay would retard the movement of spilled oil outside the bay, so that the effects on Winyah Bay would be intensified.

In addition to having severe impacts on benthic biota, hydrocarbons in the sediment can enter the food chain and be passed from prey to predator where they become a hazard to all trophic levels, including man. These persistent poisons can be reintroduced to the water column whenever resuspended by wind and wave action or dredging activities. Thus, spilled oils incorporated into upper bay sediments would act as a continuous source of contamination until exhausted years later. Ultimately, some contaminated sediments in the upper bay would reach lower bay areas, thereby increasing the extent of upper bay spills to include lower bay areas and biota as well.

c) **Middle bay impacts (cases 10 through 13)**

As shown in Table VII.C-6, the primary impacts of cases 11, 12, and 13 would occur in the middle bay (from the Belle Isle-Frazier's Point constriction to the Shell Banks near the narrow ocean end). The Atlantic Intracoastal Waterway (AIWW) and Minim and Duck creeks are the primary impact areas of spill case 10. However, tidal change following this spill would move an indeterminate quantity of oil into Winyah Bay at the Western Channel. Therefore, for the purpose of spill impacts assessment spill case 10 is included in the middle bay region.

As with spill cases 1 through 9, primary impact areas, spill volumes, occurrence dates, and other specific features of each of these four cases would vary, resulting in some variation in expected impacts (Table VII.C-6). However, any spill in the middle portion of Winyah Bay would be expected to result in the following general impacts.

The impacts of an oil spill in the middle bay would probably have the most significant deleterious effects on the Winyah Bay system, as this portion of the bay is characterized by large expanses of complex and highly productive habitats. High current velocities near the ship channel would rapidly spread the oil throughout the middle and lower bay, affecting vast acreages of marshlands (Table VII.C-6, Figure VI.C-1). Oil-contaminated water entering No Man's Friend and South Jones creeks could seriously impact hundreds of acres of Spartina alterniflora marsh within North Inlet (Allen et al., 1984).

Mud Bay, which appears to support a highly productive benthic habitat, is characterized by high sedimentation rates and low currents which would accelerate the rate of oil incorporation into sediments. Sediments in Mud Bay are not compacted and oil could penetrate and persist for years. Remineralization of nutrients by benthic organisms would be severely depressed, resulting in lower nutrient availability to primary producers. Oiling of marsh areas could result in massive die-offs of marsh vegetation. Failure of denuded areas to re-establish with marsh vegetation would result in long-term reductions in the overall productivity of the Winyah Bay estuary.

Occurrence of spill cases 11, 12, or 13 would have dramatic effects on all mid-bay trophic levels. Significant reductions in lower food chain organisms would be expected for an undetermined period of time. Zooplankton species diversity would decrease drastically as the more sensitive species are reduced in numbers or eliminated. Direct mortalities of these lower food chain organisms and sublethal effects resulting in lowered reproduction and recruitment of these organisms to the mid-bay area would have significant impacts on higher trophic level organisms such as finfish and birds.

The middle bay, in particular Mud Bay, is an extremely important nursery ground for fishes, crabs, and shrimps. Larval white and brown shrimp, blue crab, mullet, spot, croaker, and flounder enter the estuary and move to nursery areas within the system. Young shad, sturgeon, and striped bass, spawned well up the rivers, move to more saline nursery areas as they develop. There appears to be little doubt that middle bay habitats are essential for the completion of the life cycles of almost all major coastal fishery species (Allen et al., 1984).

The high larval/juvenile populations normally found in the middle bay/Mud Bay area would suffer severe mortalities following an oil spill: such an occurrence would have estuary-wide implications. Continued hydrocarbon persistence in the sediments would result in long-term contamination of both plant and animal

Table VII.C-6. Impacted areas, marsh acreages, biological activities and special considerations associated with hypothetical spills affecting middle Winyah Bay.

Spill case	Barrels and product spilled	Month	Primary[1]/secondary[2] impact areas	Wetlands acreage potentially affected[3] (primary/primary + secondary)	Significant biological activity/species affected	Special considerations
10	1,700 refined	February	AIWW, Minim Creek, Big Duck Creek, North Santee River, and North Santee Bay/Winyah Bay near Western Channel	NQ[4]	American shad juveniles in bay; mature adults migrate to ocean; Atlantic and shortnose sturgeon juveniles over-winter in mid-bay; large numbers of waterfowl present	Potential for significant waterfowl mortalities; concern for sturgeon juveniles, especially shortnose; introduction of hydrocarbons to Santee River system
11	14,000 crude	May	Winyah Bay along Cat Island and Western Channel, AIWW, and Esterville Plantation/AIWW to Minum Creek, Big Duck Creek, North Santee River and North Santee Bay, Mosquito Creek to extent of tidal excursion, width of Winyah Bay beyond Mosquito Creek	2637[5]/NQ[6]	Juvenile hickory shad descend rivers to bay; mature sturgeon migrate offshore; spotted seatrout spawn in lower estuary and offshore; highest numbers of birds nesting at Pumpkinseed Island rookery; highest seasonal movement of larvae into estuary, including white and pink shrimp, weakfish, spot, kingfish, croaker, black drum, and mullet	Long-term contamination of Esterville Plantation and Yawkey Wildlife Center; potentially significant mortalities of larval fish and shellfish resulting in lower population levels (and catches) for an extended time; tainting that prohibits human consumption; introduction of oil pollutants into the Santee River system
12	140,000 crude	April	Entire bay at narrows between North and Cat islands, Mud Bay, Pumpkinseed Island, Jones Creek, and eastern shore of Marsh Islands, Cottonpatch Creek and adjacent creeks on North Island/shoreline of South Island and Mother Norton Shoal	4485[7]/4667[8]	Same as May (spill case 11) except larval species are brown shrimp, weakfish, spot, croaker, mullet, flounder, and menhaden	Significant, persistent contamination of Winyah Bay; possible contamination of North Inlet; significant mortalities at all trophic levels; long-term reduction of productivity within the bay that would be evidenced in commercial and recreational catches for an extended time; long-term contamination of lands protected for wildlife conservation, education, and research;

Table VII.C-6. (Concluded)

Spill case	Barrels and product spilled	Month	Primary[1]/secondary[2] impact areas	Wetlands acreage potentially affected[3] (primary/primary + secondary)	Significant biological activity/species affected	Special considerations
13	2,690 crude	December	Western shore of North Island, Marsh Islands, Pumpkinseed Island, and Mud Bay/South Island	2000/2132	Highest seasonal abundance of waterfowl; American shad juveniles in bay; Atlantic and shortnose sturgeon juveniles over-winter in middle and lower bay; red drum larvae in bay	Introduction of persistent toxic hydrocarbons and heavy metals to the Mud Bay area, an important nursery area for many commercially and recreationally valuable fish and shellfish and feeding area for shorebirds and wading birds; probable contamination of South Island wetlands

1Primary impact area is that area projected to be impacted prior to a tidal change following the spill (as discussed in Sections VII.B.2.b.(2) and (4).

2Secondary impact area is that area projected to be directly impacted following a tidal change (as discussed in Sections VII.B.2.b.(2) and (4).

3Acreage was planimetered from wetlands map (Figure VI.D-1) and generally includes the entire wetland area along the shoreline affected by the spill.

4Wetlands in the spill area were not mapped; therefore, the acreage is not quantified. However, this spill could contaminate a vast acreage of wetlands.

5Value includes a 2,385-acre brackish marsh on Cat Island. Tides may or may not carry spilled oil throughout this area which is riddled by tidal creeks/ditches. Therefore, a worst case was assumed in which the entire tract would receive spilled oil.

6Acreage is not quantified since wetlands in Minum and Duck creeks and the Santee River system were not mapped.

7Includes North Island from bay mouth to just above South Jones Creek, Pumpkinseed and Marsh Islands, and Cat Island (essentially shoreline areas affected by the spill as shown in Figure VII.B-14).

8Adds wetlands on South Island (132 acres) and Mother Norton Shoals (50 acres) to the extent shown on wetlands map.

communities. The abundant amphipod populations in Mud Bay, a particularly important food source that is extremely susceptible to oil pollution, may be substantially reduced as the result of an oil spill in the middle bay region (Allen et al., 1984).

Reduced populations of recreationally and commercially important shellfish and finfish would be expected for an undetermined period of time following a spill in the middle bay region, as hydrocarbon-sensitive larvae are killed outright, hatching success of exposed embryos and survival of newly hatched larvae are reduced, and adult spawning and migration patterns are interrupted. Large concentrations of adults could result in the occurrence of a massive fish kill. Recreational and commercial catches in the bay would be eliminated immediately following occurrence of a middle bay spill and would be significantly reduced for an undetermined amount of time. Tainting of fish and shellfish would prohibit human consumption of surviving individuals for probably an extended time. Damage to shellfish resources in North Inlet would be severe and long-lasting should oil enter this area.

Occurrence of spills that would result in immediate contamination of Mud Bay (clearly cases 12 and 13) would result in the most direct and adverse effect on birds. Contamination of Mud Bay and its associated tidal flats along with the Pumpkinseed Island rookery area during the period of highest nesting bird concentrations would have a devastating impact on Winyah Bay's colonial nesting bird population. Over 40,000 birds use this rookery annually; count statistics show highest numbers of birds in April and May when nesting activities begin. (Hypothetical spill cases 12 and 13 occur in April and May, respectively.) Particularly important feeding areas for these birds are the North Inlet marshes and the perimeter of Mud Bay. Direct mortality would be expected to be severe, decimating local populations. Sublethal effects would include reduced reproductive activity, decreased egg production and hatching success, and reduced survival of offspring. At the worst, Pumpkinseed Island would cease to be used as a rookery by colonial wading birds; at the best, significantly reduced populations could be anticipated for perhaps quite a number of years. These waterbirds are an integral part of the Winyah Bay ecosystem and are probably responsible for some of the greatest interchanges of energy between aquatic and terrestrial systems.

Additional concerns associated with spills affecting the middle bay region include possible contamination of the Yawkey Wildlife Center, a 20,000-acre, state-managed wildlife area that includes the lower one-third of the Winyah Bay shoreline and North and South islands and that is an unparalleled refuge for migratory waterfowl, wading birds, and several endangered and threatened wildlife species; Baruch Institute, which occupies 17,000 acres of forest land and tidal marshes comprising most of the eastern bay shoreline; and the North Inlet Estuary, which has been designated as an Ecological Experimental Reserve by the National Science Foundation. Of great importance to the national research effort, the North Inlet estuary is the only marine-oriented ecosystem in the United States to be part of the Long-Term Ecologial Research Program. Nowhere else in the United States is there an estuary possessing the characteristics of North Inlet; contamination of this ecosystem would not only result in the loss and degradation of uniquely valuable natural resources, it would also hinder national research efforts in this country aimed at better

understanding the functioning of estuaries and their associated value to man. North Santee River and North Santee Bay may also receive oil pollution via the AIWW from spills occurring in the middle bay area or the AIWW (spill case 10).

The overall productivity of Winyah Bay would be severely reduced for an extended period of time following occurrence of a spill that reaches the middle bay. Natural, economic, and research values associated with the bay would be seriously and adversely affected. The continued viability of the bay as a highly productive estuarine system and as a uniquely protected area for wildlife management, education, research, and conservation purposes would be questionable should a spill result in widespread contamination of this important and productive middle bay region.

Occurrence of spill case 10, which would have less impact than cases 11, 12, and 13 on Winyah Bay proper, would quickly foul the breath of the AIWW. As the tide ebbs (spill occurs at slack high tide) oil would move into Minim and Big Duck creeks, the North Santee River, and North Santee Bay. Due to the acute toxicity of refined oils, significant mortalities of aquatic life in the spill area could be expected immediately.

Much of this spill would interact with suspended particles and settle to and penetrate into bottom sediments. Fouling of shorelines would occur as the tide receded. Oil incorporated in sediments would be persistent and toxic for many months. As the tide changed, an indeterminate quantity of oil would also move up the AIWW to Winyah Bay where it would again serve as a chronic source of hydrocarbon contaminants for an indeterminate time.

Occurrence of either spill case 11, 12, or 13 involving 14,000, 140,000, and 2,690 barrels of crude oil, respectively, in the late spring would result in long-term contamination of middle bay sediments. Oil settled on the bottom would persist for years, especially in the Mud Bay area which serves as a sediment sink, as contaminated sediments are buried by additional sediment influxes that preclude aerobic biodegradation. Subsequent resuspension of contaminated sediments would reintroduce toxic hydrocarbons and heavy metals into the water column.

Due in part to the fact that Mud Bay is a sediment sink, spill cases 12 and 13 would be expected to have longer lived impacts on the bay's resources. The total spill of case 12 (140,000 barrels) would severely damage the aquatic resources of the entire Winyah Bay estuary. Because of the large volume and the inclosed nature of Winyah Bay, the effects of such a spill would persist for many years. Impacts of spill case 11 include the potential oiling of Esterville Plantation as well as the AIWW. Contamination of Cat Island marshes would result in severe detrimental impacts. Long-term reductions in commercially and recreationally important fish and shellfish as well as important forage species and other food organisms would be expected as the result of spills 11, 12, and 13. Long-term contamination of valuable state and/or privately owned lands reserved for wildlife conservation, research, and education would result from occurrence of these three spills (Table VII.C-6).

d) Lower bay impacts (case 14)

Hypothetical spill cases 12, 13, and 14 are projected to impact the lower bay, that narrow area below Shell Banks to the ocean. While it is anticipated that high river discharges and the deployment of containment devices would prevent

Table VII.C-7. Impacted areas, marsh acreages, biological activities and special considerations associated with hypothetical spills affecting lower Winyah Bay and ocean coastline.

Spill case	Barrels and product spilled	Month	Primary[1]/secondary[2] impact areas	Wetlands acreage potentially affected[3] (primary/primary + secondary)	Significant biological activity/species affected	Special considerations
14	14,000 crude	April	Western shore of North Island; Cat Island/ entire shoreline below narrows in vicinity of Cat Island (this scenario assumes deployment of containment devices to prevent spill from reaching middle bay) and open coastal waters	199[4]/381[5]	Juvenile hickory shad descend rivers to bay; mature sturgeon migrate offshore; spotted seatrout spawn in lower bay/offshore; highest numbers of shorebirds nesting on Pumpkinseed Island; highest seasonal movement of larvae into estuary, including brown shrimp, weakfish, spot, croaker, mullet, flounder, and menhaden	Accumulation of persistent toxins in marsh sediments along Cat Island, South Island, and North Island
15	140,000 crude	September	Coastal area from South Island southward to Cape Romain (approximately 24 hours after spill)	NQ[6]	Mature hickory shad migrate offshore; weakfish and mullet migrate offshore to spawn; loggerhead turtle nesting activity extends into September; highest seasonal abundance of pink and white shrimp and blue crab; large numbers of shorebirds still present	Disruption of loggerhead turtle nesting; long-term contamination of state and federally-owned wildlife management areas/wildlife refuges; accumulation of persistent toxins in extensive marshlands of Santee River system and Cape Romain National Wildlife Refuge; loss of a nationally unique and valuable resource area protected for wildlife conservation and protection, education, and research
16	140,000 crude	April	North Inlet and Debidue Beach/shoreline fouling for an indeterminate distance to the north	5640[7]/NQ[8]	Same as spill case 14	Introduction and incorporation of persistent toxins in North Inlet sediments; possible long-term contamination of 5640 acres of pristene salt marsh; loss of North Inlet value to national estuarine research effort; beach fouling that could effect nesting of loggerhead turtles

[1]Primary impact area is that area projected to be impacted prior to a tidal change following the spill (as discussed in Sections VII.B.2.b.(2) and (4).

Table VII.C-7. (Concluded)

[2]Secondary impact area is that area projected to be directly impacted following a tidal change (as discussed in Sections VII.B.2.b.(2) and (4).

[3]Acreage was planimetered from wetlands map (Figure VI.D-1) and generally includes the entire wetland area along the shoreline affected by the spill.

[4]Includes 99 shoreline acres along lower western shore of North Island and 100 acres along shoreline of Cat Island at narrows of the bay.

[5]Adds 132 acres on South Island and 50 acres on Mother Norton Shoals; this does not include all affected wetlands on South Island or Mother Norton Shoals but only those portions shown on the wetlands map.

[6]Not quantifiable: wetlands of this area were not mapped but are quite extensive.

[7]This acreage represents North Inlet salt marsh acreage as reported by Tiner, 1977.

[8]Not quantifiable: entire area not mapped and actual extent of spill undetermined.

oil from spill case 14 from penetrating Winyah Bay beyond the narrows in the vicinity of Cat Island, spill cases 12 and 13 would extend into the middle bay (see preceeding section). Table VII.C-6 and VII.C-7 list conditions and impacts specific to each of these spills; the following discussion centers only on the lower bay impacts of these spills.

Low nutrient concentrations and phytoplankton densities near mid-channel in the lower bay would probably not be significantly affected by an oil spill. The greatest damage to primary producers and nutrient regimes in the lower bay would occur if oil entered tidal creeks on Cat and South islands, and to a lesser extent North Island, which are bordered by vast marshlands. Oiled vegetation would experience massive mortality and nutrient concentrations would concomitantly decrease. Rich benthic communities which are normally present in such areas may experience the most dramatic consequences. Productivity in these areas could be affected for several years.

High zooplankton species diversity in the lower bay would decrease as more sensitive species are replaced by less sensitive ones. However, zooplankton populations would not be expected to experience serious long-term effects since recruitment from adjacent near shore and upper estuary sites would be rapid, if spill impacts are confined to the lower bay. Effects upon the abundant meroplankton in the lower estuary including crab megalopae, barnacle nauplii, and echinoderm larvae would be similar to those observed for other members of the zooplankton community.

Populations of crustacean larvae including shrimps and crabs which are very abundant in the lower bay would be affected to some extent by the oil. However, since most shrimps, crabs and larval fishes are migrating to more suitable nursery grounds near the middle of the estuary and are not feeding for prolonged periods in the lower bay, impacts to these organisms would probably be less severe here than at sites located further up the bay. Also, oil deposited in the lower bay, where coarse-grained sediments are exposed to rapidly moving currents, would not be persistent. Oils reaching compacted tidal flats or fine-grained beaches, as exist on North Island, would not penetrate the surface.

Therefore, the major long-term impact of spill cases 12, 13, and 14 on the lower bay section would result from oil that reaches the shoreline and penetrates marshy areas along South, Cat, and North islands (Table VII.C-6 and VII.C-7). Massive mortality of heavily-oiled marsh grasses would be expected, while those grasses exposed to lower oil concentrations (e.g., more inland areas of Cat Island through which a complex of small tidal creeks run) would exhibit reduced growth and production. Failure of denuded shoreline marshes to revegetate would have severe and long-term ecological impacts, as would the persistence of hydrocarbons in marsh sediments.

e) **Offshore impacts (cases 15 and 16)**

To complete the assessment of potential oil spills associated with operation of the CRDC refinery, two offshore spill scenarios (cases 15 and 16) were modelled. In case 15, 140,000 barrels of crude oil are spilled 4 miles east of the Winyah Bay Harbor entrance channel. Shoreline fouling from South Island to Cape Romain would occur (Table VII.C-7). Oil would penetrate marsh sediments along this shoreline; oil could also penetrate coarse-grained sand beaches. By slack low tide the spill centroid would be located off the mouth of the North Santee Bay. Subsequent flood tide would be expected to drive oil into the tidal inlets in the area, fouling adjacent marshes.

The most significant impacts associated with this spill would occur when the crude oil enters Cape Romain Harbor and makes landfall in the extensive marsh areas of this National Wildlife Refuge. The funnel-shaped entrance to Cape Romain Harbor would effectively direct the spill into the Romain River and surrounding marshlands. An unknown but significant volume of oil could be expected to persist here for years after it penetrates the sediments. Long-term persistence of hydrocarbons in these marsh sediments would have devastating impacts on these highly productive and valuable ecosystems. A large but undefined volume of the spill would become incorporated into the water column or be deposited in offshore bottom sediments.

AD-A152 525 FINAL ENVIRONMENTAL IMPACT STATEMENT FOR OIL REFINERY GEORGETOWN SOUTH CAROLINA VOLUME 1(U) CORPS OF ENGINEERS CHARLESTON SC CHARLESTON DISTRICT SEP 84 5/5

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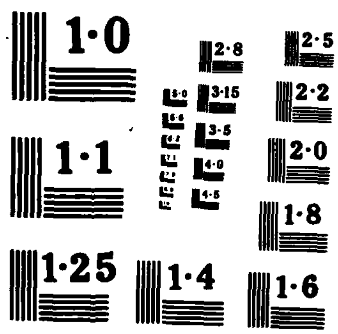
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The coastal area that would be affected by occurrence of spill case 15 is one of the most significant and extensive natural coastal areas in America, containing such areas as the Cape Romain National Wildlife Refuge, Santee Coastal Reserve, and Yawkey Wildlife Center. The large areal extent of these undeveloped lands considered together as a single resource unit, combined with the long history of protection for the purposes of wildlife management, education, research, and conservation, underscores the significance of the area as a haven for migratory waterfowl and rare, threatened, or endangered wildlife species. Although currently unquantifiable, the occurrence of a spill such as that described in spill case 15 would undoubtedly have a devastating effect on the extremely valuable resources of this nationally unique area.

Spill case 16 involves the loss of 140,000 barrels of crude oil 8 miles east of the Winyah Bay Harbor entrance channel. Tidal and wind conditions at the time of this spill would carry oil to the beaches of North Inlet. Oil would not penetrate measurably into the fine-grained beach sand, thus facilitating cleanup. Without cleanup, however, oil could persist on the beaches for several months. Benthic biota as well as shorebirds would be adversely affected.

Oil entering North Inlet would flow into North Island and Waccamaw Neck creeks along with high salinity waters where it would flocculate and precipitate to the bottom. Spilled oil entering the marsh areas would penetrate into the sediments and persist for years. Debidue Beach would receive fouling, and remobilization of oil and longshore currents could cause shoreline fouling for an indeterminate distance to the north.

Occurrence of spill case 16 would result in extensive contamination of one of the most pristine marsh estuaries on the east coast (Table VII.C-7). Thousands of acres of salt marsh could be affected and even if only a small portion of the affected area experiences lethal effects, the impacts on the estuary's primary and secondary productivity would likely be significant. The marsh creeks of North Inlet are populated by large numbers of finfishes, most of which are juveniles. The diversity and abundance of fishes, especially during the summer, indicate that these creeks are very important nursery areas for coastal species. A spill of the magnitude of spill case 16 would be disastrous for these fishes, many of which are of commercial and recreational importance in South Carolina. Declines in local landings of these species could follow the occurrence of spill case 16. Valuable shellfish resources in North Inlet would be severely affected for a long period of time.

Contamination of North Inlet would not only result in the loss and degradation of uniquely valuable natural resources, it would also hinder national research efforts in this country aimed at better understanding the functioning of estuaries and their associated value to man. This estuary, designated as an Ecological Experimental Reserve by the National Science Foundation (NSF) is the only estuarine site in the United States funded for study under the NSF's Long-Term Ecological Research Program.

f) **Summary and long-term ramifications**

Both crude and refined oils contain numerous organic compounds that are extremely toxic to many species, and occurrence of any of the seventeen hypothetic spill cases would result in immediate and severe impacts on organisms coming in contact with the spilled oil. Refined products, included in seven of

the spill cases, contain the paraffins, naphthenes, and aromatics present in crude oil plus the products of the cracking process. While degradation of refined products would proceed more rapidly than degradation of crude oil and refined products would be generally less persistent than crude oil, these highly toxic products could nonetheless persist for months or years. Massive biota die-offs within the area affected by the spill would be expected immediately following a refined product spill and sublethal effects would occur as long as the spilled products persist in the environment.

Of the seven spills involving refined products, five involve the spillage of only refined products (spill cases 1, 4, 8, 10, and 17). Immediate, significant local mortalities of aquatic biota (both plants and animals) would occur as a result of the highly toxic nature of the more volatile components of refined oil products. While these volatile components would be prone to rapid evaporation, thick spills that include crude oil (cases 2 and 9) may form a crust that traps these volatile toxics in the water column underneath until mechanical forces such as wave action break the crust and restart the evaporation cycle. Acute toxicity of the spill would then be extended an indeterminate period of time.

The expected formation of relatively stable oil-in-water emulsions would greatly increase the amount of oil in the water column and significantly increase the area that would be impacted by these spills. Correspondingly greater adverse effects on aquatic biota would be expected.

While some evaporation of spilled refined products would occur, evaporation would not remove a major percentage of the volume from the aquatic ecosystem. Unevaporated portions would interact with suspended particles and be deposited on bottom sediments. Direct dissolution would also result in oil incorporation into bottom sediments. Persistence in the sediments could be eight months or more, with toxicity existing much of this time.

Approximately 50 to 70 percent of Bachaquero crude is made up of asphaltenes which can be expected to be incorporated into sediments of Winyah Bay within a short time of spill occurrence. The incorporation and persistence of crude oil in the bay sediments are a major ecological concern as crude oil is in fact a long-lasting poison that resembles DDT, PCB, and other synthetic materials in its longevity. Hydrocarbons from oil spills enter the food chain and are concentrated in organisms, often thousands of times the concentration present in sediments or water. These poisons are thus passed from prey to predator in ever higher concentrations until they affect all trophic levels, including man.

While the occurrence of any of the 12 hypothetical crude oil spills would result in immediate mortality of many organisms that come in direct contact with the spilled crude oil (either because of acute toxicity or physical coating by the oil), probably the major ecological concern is the expected persistence of hydrocarbons in bay sediments. Each of the 12 crude oil spills would result in flocculation or direct dissolution of oil to the bottom where it would become incorporated into the sediments and act as a continuous source of hydrocarbon and heavy metal contamination until exhausted years later. In addition, the incorporation of oil into sediments inhibits the normal uptake and release of soluble nutrients, metals, and organic substances to the water column. This results in lower nutrient availability to photosynthesizing plants, affecting primary and thus secondary productivity of aquatic systems affected by crude oil spills and resultant sediment contamination.

Occurrence of any total loss spill within Winyah Bay would be devastating. It is likely that several tens of thousands of barrels of oil would enter the sediments. Because of the large volume of oil involved and the inclosed nature of Winyah Bay, the effects of such a spill would persist for many years.

Offshore spills, such as cases 15 and 16, that would foul the North Inlet estuary and/or the coastline south of Winyah Bay would significantly and adversely affect fish and wildlife resources of national importance. This coastal area is one of the most significant and extensive coastal areas in America. There is a long history of protection of this area for purposes of wildlife management, education, research, and conservation. The devastating effects that a spill would have on this extremely unique and valuable area would result in the loss of an incomparable and irreplaceable national resource.

d. **Effects on Endangered Species**

1. **American alligator**

The impoundments which surround the project area are prime nesting habitat for alligators. Because Winyah Bay and its tributaries are the major water supply for these impoundments, any oil spill affecting Winyah Bay could also affect the impoundments.

If the water control structures were open at the time a spill reached them and oil were allowed to enter the impoundments, toxic components in the oil would settle into the sediment and surrounding marshy areas and would not easily be removed. Many studies have indicated that toxic aromatic hydrocarbons incorporated into the sediment layers are not quickly weathered and remain toxic for longer periods of time than those deposited in areas exposed to wind and wave action. This results in a chronic leakage of toxic materials into the system over periods as long as ten years (Laubier, 1980). The effects of oil pollution on alligators has not been reported in the literature. However, in view of the documentation of toxicity of petroleum hydrocarbons to the eggs of various birds and reptiles, it is likely that a substantial amount of oil pollution in the impoundments would reduce hatching success and possibly kill young alligators if the spill occurred during the nesting season.

2. **Atlantic loggerhead sea turtle**

Very little information is available on the effects of oil contamination on loggerhead eggs and hatchlings. Fritts and McGehee (in press) did not find a significant difference in hatching success for nests in clean dune sand versus oiled sand while studying post-spill beaches oiled by the Ixtoc I spill at Rancho Nuevo on the Gulf of Mexico. Follow-up laboratory observations revealed

that embryos in earlier stages of development are not as sensitive to the toxic components of oil as older embryos. Minimum incubation time for the eggs was not influenced by oil treatment, however there seemed to be some effect on the time required for hatchlings to emerge from the eggs. Nests treated with light oiling produced hatchlings which emerged more quickly than controls, whereas medium and heavy oiling resulted in slower emergence than controls. Morphology of hatchlings, particularly scutellation, appeared to be affected by oiling with the most significant deviations occurring in association with those nests exposed to medium and heavy oiling. These differences were noted only in those nests which were exposed to oil throughout the incubation period. Nests oiled in later stages of incubation exhibited no morphological anomalies.

The spill type most likely to affect loggerhead eggs and hatchlings would be a major spill occurring during the summer months which would reach the islands at the mouth of Winyah Bay and those to the south, where ideal and heavily used nesting habitat of the loggerhead sea turtle would be adversely affected. Most of these islands are low profile beaches and subject to overwash during high tides. Since the effects of even a large oil spill are relatively short-lived on high energy beach shorelines, adverse effects of such a spill with reference to loggerheads may be limited to a single year's reproductive effort.

Adult loggerheads may ingest toxins from discharges or spills through the food chain. Since loggerhead normally feed on crabs and similar bottom-dwelling organisms in inshore areas, they may be indirectly affected by an oil spill due to changes in abundance or distribution of their preferred food species.

Direct impacts to the turtles may also occur if they surface in an oil slick. Mortality has been observed among young turtles exposed to oil. Also, stranded turtles have been found with tar balls in their mouths. While it cannot be proven that the tar killed the turtles, it is possible that disruptions of respiratory and/or feeding processes were contributing factors in their deaths. Compounds in oil such as 3-4 benzopyrene or other polycyclic aromatic hydrocarbons are carcinogenic or mutagenic (Scarratt, 1981). Thus, oil could produce cancers, tumors or other disorders in turtles, possibly affecting the long-term survival of individuals. It is likely therefore, that an encounter with oil would result in the death of some individual turtles. Young turtles are especially vulnerable.

Small spills at the Port Authority Dock may have some sublethal impacts on loggerhead turtles if they feed in contaminated areas.

3. Eastern brown pelican

As with many other endangered and threatened species, there appears to be little documentation of the effects of oil on brown pelicans. Adult pelicans may be somewhat behaviorally shielded from direct mortality as an area covered by an oil slick would be unattractive as a feeding area because of the opaque nature of the oil on the water. This observation is supported by the literature, which indicates that birds which typically fly over the surface of the water to feed are affected much less frequently by oil spills than species such as diving ducks which spend much time on the water and dive from the surface for their prey (Szaro, 1977).

Adult pelicans would most likely suffer indirect adverse effects of spills that

would damage their food source. Oiling of Mud Bay and other pelican feeding areas in Winyah Bay would damage populations of small fish such as menhaden, mullet and pinfish on which the pelicans feed, either directly or through biomagnification of sublethal toxins through the food chain.

The danger to pelicans from oil pollution may be more serious due to effects on reproduction. The highly toxic effects of very small quantities of crude oil and refined products on bird embryos is well documented in the literature. Microliter amounts of certain crude and refined oils applied to the surface of eggs cause high embryonic mortality in the lab and in the nest. Morphological defects (bill, brain, eye, skeletal, and visceral anomalies) accompanied by stunted growth have also resulted. The contributing factors to overall embryotoxicity include both aromatic hydrocarbons and heavy metals (Hoffman, 1978). If spills occur during the nesting season, oil can be transferred to eggs from the feathers or feet of incubating adults resulting in severe reductions in egg hatchability (Albers, 1980). Some crude oils on the surface of the water in amounts of as little as 100 milliliters per square meter have resulted in total hatching failure in experimental mallards. Embryos appear to be particularly sensitive to the toxic components of oil in the first ten to fourteen days of incubation (Albers, 1980; Dieter, 1977).

Because Winyah Bay is not a preferred feeding area and because of the brown pelican's tendency to avoid oil spills, it would seem unlikely that significant mortality of adults would occur in the event of a spill. Similarly, the probability of enough incubating adults being contaminated with sufficient amounts of oil to cause massive egg mortality at the rookeries would appear to be small. There is the remote possibility that a catastrophic spill at the mouth of Winyah Bay, combined with extremely high tides, could result in overwash of the nearest low lying rookery island at Cape Romain National Wildlife Refuge and mortality of eggs and young by direct contamination. In this event, nests would be destroyed and many eggs washed away. Brown pelicans are known to be persistent re-nesters (Blus et al., 1974) and most would probably return to the island to reinitiate nesting. If re-nesting occurred before sufficient weathering of the oil on the sand could take place, heavy embryonic mortality could occur. It is expected that the adults in this case, not realizing that anything was wrong, would continue to incubate the dead eggs. In this event, total loss of one year-class of young could occur. The likelihood of this scenario actually taking place, however, is remote due to the limited period of vulnerability and the distance of the rookery from the projected spill area.

4. Bald eagle

Adult eagles, because of their feeding habits, are generally not in contact with the water for long periods of time and are thus less susceptible to being oiled to the point of incapacitation than are other species which rest on the water and dive for fish. Immature eagles have been observed to actually splash into the water when fishing, unlike adults which usually only touch the water with their feet. This would seem to make these immatures more susceptible to being oiled.

As with the pelican, the primary danger to eagles from oil pollution would appear to be adverse effects on reproduction, caused by contamination of the eggs by adults carrying oil on breast feathers and feet. Because eagles are such opportunistic feeders, it seems likely that they would be attracted to the site of an oil spill if dying fish and floundering waterfowl were present. Therefore the effects of oil ingestion must be considered as well. Ingestion of fresh south Louisiana crude oil has been shown to reduce egg production in mallards when they are fed diets containing 2.5 % crude (Eastin and Hoffman, 1979). A diet containing 5 % fresh south Louisiana crude oil fed to mallard ducklings from the time of hatching until eight weeks of age resulted in retarded growth and flight feather development, enlargement of livers due to increased hepatic function (no cellular damage was demonstrated), and reduction in spleen size (Szaro, 1977). Adult ducks fed similar diets do not appear to react as negatively as ducklings, indicating that adult waterfowl may be able to tolerate higher concentrations of petroleum hydrocarbons than ducklings (Eastin and Hoffman, 1979). Crude and refined oils which have been allowed to weather for at least two to three weeks have been shown to be less embryotoxic, indicating that the most deleterious effects of a fresh oil spill would be on embryonic survival.

In the event of a large oil spill in Winyah Bay during the bald eagle nesting season, it is possible that adults from all five adjacent territories might be attracted to the area by dying fish and birds. If the attraction of the prey overcame any natural reluctance the eagles might have to entering the spill area, it is possible that sufficient oil could be carried back to the nest by the adults to cause total hatching failure. If eggs had already hatched and young were present in the nest, there could be some effect on their growth rate and development if the adult birds returned to the nest and fed oiled prey to their chicks. It is unknown whether eagles would reject prey containing substantial amounts of oil because of the assumed lack of palatability. When combining the probability of a large spill occurring in an area where eagles feed with the probability that adults from all five active territories would be oiled in sufficient quantity to cause embryological death, and the probability that this spill would occur at a time when all the nests contained developing eggs rather than hatchlings, the worst case situation of loss of an entire year-class of young from these five nests seems quite remote. In the event this should occur, however, the loss of one year's young from a third of South Carolina's nesting eagle population would undoubtedly be a setback in the species' slow progress toward recovery in this area.

5. Shortnose sturgeon

Of all the endangered species, the effects of both chronic discharges and oil spills would be greatest on the shortnose sturgeon. Its vulnerability is directly related to life cycle habitat requirements.

Shortnose sturgeon are bottom-dwellers and strictly benthic feeders. Adults eat molluscs, insects, crustaceans, and small fish; juveniles eat crustaceans and insects. Because of this benthic existence and food source, contact with spilled oil is certain. Through oiling, their food source may be eliminated, reduced, or contaminated for considerable time periods. Adverse effects of oil

on sediments and benthos were reported from the barge Florida spill off West Falmouth, Massachusetts, five years after the accident (Sanders et al., 1980).

Shortnose sturgeon in Winyah Bay may be killed as a direct result of an oil spill (NMFS, 1982a). McCain and Malins (1981) observed mortalities in demersal fish exposed to hydrocarbon-contaminated sediments. Oil spill scenarios presented elsewhere in this document show oil coating both Mud Bay, a documented overwintering area for the sturgeon, and the lower sections of the Waccamaw, Black and Pee Dee rivers (Waccamaw Point), a documented over-summering area (see Figure 3. Sturgeon may be adversely affected by the contamination of sediment from oil spills.

The effects of chronic discharges of oil and minor oil spills on shortnose sturgeon in Winyah Bay are more difficult to assess; little information on effects of oil pollution on shortnose sturgeon is available. However, it has been determined that components of oil are carcinogenic and mutagenic (Scarratt, 1981). Shortnose sturgeon may be particularly susceptible to these sublethal abnormalities since they may live ten years or longer and thus may be exposed to and accumulate hydrocarbons over a long period of time. Potential effects of oil pollution on the reproductive capability of shortnose sturgeon may also be a consideration. In a case study of the Tsesis oil spill a reduction in the spawning success of herring, an anadromous species with spawning requirements and characteristics similar to those of the sturgeon, was reported (Linden et al., 1979b).

Based on projected impacts to the shortnose sturgeon from chronic and accidental oiling of their habitat as a result of the CRDC refinery project, the National Marine Fisheries Service (NMFS) has written a "jeopardy opinion" for this species pursuant to Section 7(b) of the Endangered Species Act of 1973, as amended.

3. LAND-USE CHANGES

a. From Plant Construction

Approximately 100 acres of undeveloped uplands providing marginal wildlife habitat would be converted to industrial development at the refinery site due to plant construction.

b. Oil spills

Land use changes associated with oil spills would depend on the circumstances of the spill. Large or repeated small spills would cause an overall decline in the primary and secondary productivity of the Winyah Bay system. Winyah Bay is surrounded by marshes and other natural areas, much of which are maintained in the public trust by State agencies and institutions and are considered to be of unusual value. Oil spills could cause extensive long-term damage to these areas and the special uses they now or may have in the future.

If oil from a spill should enter the North Inlet estuary, it could affect the research of the Belle W. Baruch Institute for Marine Biology and Coastal Research. The North Inlet estuary is the only estuarine site in the United States funded for study under the National Science Foundation's Long Term ecological Research Program. The funding and continuing research effort are based on the pristine nature of the North Inlet system.

Should oil enter the impoundments of the Yawkey Wildlife Center or the Samworth Game Management Area, the utility of affected impoundments to waterfowl could be greatly reduced. The many large private impoundments managed for waterfowl hunting could be similarly affected by oil spills, with the extent of damage being determined by the circumstances of the spill.

4. ALTERNATIVES ANALYSIS

a. Refinery sites

1. Harmony Plantation, Georgetown, S.C.

This is the site on which CRDC proposes to build its oil refinery as advertised in Public Notice number 79-5R-319. A description of this site and the environmental consequences of development at this site are discussed in previous sections of this document.

2. Myrtle Grove, Georgetown, S.C.

1) Effects of Plant and Pipeline Construction - The habitat at this site is very similar to that occurring at the Harmony Plantation site, although canopy cover appears to be greater at this site. For these reasons, the direct impacts of plant construction on terrestrial wildlife are expected to be similar, but perhaps displacement of slightly larger wildlife populations may occur. Indirect impacts to aquatic organisms caused by runoff and turbidity generated at the construction site would affect less of the Sampit River because the site is located downstream. However, the segment of the Sampit River that would receive these discharges is already stressed from the International Paper Company discharge located approximately across the river. Therefore, the cumulative effects of additional discharge on the aquatic biota are anticipated to be more direct at this site. Also, its closer proximity to Winyah Bay would increase the probability of these discharges reaching and affecting Winyah Bay biota.

The impact of pipeline construction would be slightly less than at the Harmony site because the Myrtle Grove site is closer to the oil transfer terminal so less of disturbance corridor would be created.

2) Effects of Plant Operation - Impacts due to plant operation at the Myrtle Grove site are anticipated to be similar to those described for the Harmony

Plantation site with regard to spills, and slightly greater with regard to chronic discharges. Chronic discharges associated with refinery operation would enter the Sampit River closer to the mouth. This may present less direct impact to mid and upper portions of the Sampit River. However, the cumulative effects of the refinery discharge in association with other industrial pollutant discharges occurring in the lower Sampit River would be greater on the biota of the lower Sampit River because of the closer proximity of the discharge points. Also, less of the Sampit River would be available to act as a buffer for Winyah Bay. Therefore, there is a greater opportunity for refinery discharges reaching and affecting Winyah Bay biota.

3. **Charleston, S.C.**

1) Effects of Plant and Pipeline Construction - In general, effects would be similar to those described for the Harmony Plantation alternative. Approximately 100 acres of habitat would be eliminated for plant construciton. Impacts to wildlife would vary depending on the type and quality of habitat at the site. Indirect impacts to aquatic biota of the Cooper River due to site runoff during construction would occur in a similar manner as those described for the Sampit River under the Harmony Plantation alternative.

2) Effects of Plant Operation - Chronic pollutant discharges associated with refinery operation would have similar effects on the biota of the Cooper River as those described for the Sampit River under the Harmony Plantation alternative. Adverse effects on the biota of Charleston Harbor from oil spills would be similar to those acute and chronic effects of petroleum on organisms described earlier in this document. However, shipping hazards, oil spill probabilities, oil spill trajectories and spread and clean-up potentials would be different for Charleston Harbor and the Cooper River and require extensive, independent analysis upon which to base predictions. In general, the sensitivity and vulnerability of Charleston Harbor to oil spills appear less than the Winyah Bay system. This is mainly attributable to the greater development of extensive marsh and sheltered tidal flat and shallows in the Winyah Bay system. The presence of large tracts of land set aside for conservation and scientific research in Winyah Bay is also a unique feature of the Winyah Bay estuary making it more sensitive to oil spills than Charleston Harbor. However, the Charleston Harbor site was eliminated from consideration as a result of air quality standards limitations.

4. **Other unspecified sites in South Carolina**

Thorough examination of alternative sites in South Carolina was not conducted because such sites would not meet the needs of the applicant who was unable to identify satisfactory market conditions outside of Charleston and Georgetown.

1) Effects of Plant and Pipeline Construction - Assuming a site meeting the above criteria could have been identified, the effects of plant and pipeline construction in general would have been similar to those described for the Harmony Plantation alternative. However, site specific information would be necessary as impacts to wildlife would vary depending on the type and quality of habitat at the site. Indirect impacts to biota in the adjacent aquatic system due to site runoff during construction would occur in a similar manner as those

described for the Sampit River under the Harmony Plantation alternative.

2) Effects of Plant Operation - Chronic pollutant discharges associated with refinery operation would have similar effects on the biota of the receiving body as those described for the Sampit River under the Harmony Plantation alternative. The degree of adversity and/or resultant changes in community composition in the receiving body would be dependent on site-specific baseline chemical and biological conditions.

Adverse effects on aquatic biota from oil spills would, in general, be similar to those acute and chronic effects of petroleum on organisms described earlier in this document. However, the degree of adversity and/or resultant changes in community composition in the receiving aquatic system would be dependent on site-specific baseline chemical and biological conditions. Shipping hazards, oil spill probabilities, oil spill trajectories and spread and clean-up potentials would likewise be site-specific and require extensive, independent analysis upon which to base predictions. In general, the extensive development of shoreline marsh and prevalence of sheltered tidal flat and shallows, as well as the large tracts of shoreline lands set aside for conservation and scientific research in Winyah Bay, make it one of the most sensitive aquatic areas in the State to the effects of an oil spill.

b. <u>Pipeline Routes</u>

1. Under the Sampit River

This is the alternative advertised in Public Notice 79-5R-319. Impact analysis of this alternative is presented in a previous section of this document.

2. Suspension of pipelines from the U.S. Highway 17 bridge

This alternative would have little, if any, direct impact on aquatic biota of the Sampit River from construction, since bottom sediments would not be disturbed. However, pipeline rupture would result in similar spill impacts whether suspended from the bridge or buried under the river. Upland buried segments to reach the refinery site would be the same as discussed for the "Under the Sampit River" alternative.

3. Around the Sampit River

This alternative would have little direct effect on Sampit River bottom communities since bottom sediments would not be disturbed. However, greater disturbances to upland and tributary creek and wetland systems would be anticipated.

c. <u>Other Methods of Handling Oil</u>

1. Port Authority Dock

This is the alternative advertised in Public Notice 79-5R-319. Impacts to aquatic biota from this alternative are directly related to the amounts, type and frequency of oil spilled during the transfer process at the dock and through

pipeline leaks to and from the refinery. Since the public notice advertises a proposed two-way pipeline system between the docks and the refinery (i.e., crude oil from tanker to dock to refinery through pipeline and refined product from refinery through pipeline to dock and tanker) spills of both crude and refined oil must be considered at the dock and along the pipeline route. Since refined oil is known to be more toxic than crude oil, impacts from refined oil spills are anticipated to be greater. Direct effects of spilled oil at the dock and/or pipeline alignment would be manifested upon the aquatic biota of the Sampit River and Winyah Bay in a manner similar to the acute and chronic effects of petroleum on organisms described earlier in this document. The geographic extent of these adverse effects would depend largely on conditions at the time of the spill (tide, wind, current velocities) and the ability to contain the spill. Since the petroleum transfer site represents the most likely site for a spill, cumulative impacts due to small, repeated and chronic spills would be anticipated. For further discussion refer to sections of the document dealing with chronic discharge and small spill scenarios at the pier and pipeline.

2. Mooring and pumping facilities on the south shore of the Sampit River directly across from the Port Authority Dock

Since this alternative would eliminate the need for a pipeline crossing under the Sampit River, it would avoid the temporary disturbances to the bottom community of the Sampit River associated with such a crossing. However, construction of the new facilities would require disturbance and probable destruction of some marsh fringe communities on the south side of the Sampit River. It is also anticipated that new and maintenance dredging requirements and associated impacts would accompany this alternative. Dredging associated impacts would include increased turbidity and alteration of benthic community structure and composition.

The effects and projected periodicity of oil spills during transfer operations from this location would be equivalent to those discussed for the Port Authority Dock alternative.

3. Single point mooring system

By locating the oil transfer point offshore, this alternative would eliminate the potential impact of shipping and handling spills on the biota of the Sampit River and upper Winyah Bay. However, oil spills during transfer at this offshore facility could impact lower Winyah Bay and coastal areas including North Inlet, the Santee Delta, and portions of Cape Romain National Wildlife Refuge. Such a system would encourage use of much larger tankers, thereby creating the potential for larger spills.

d. <u>Larger or Smaller Refineries</u>

1. A larger refinery at Savannah, Georgia

By eliminating any refinery at Georgetown, South Carolina, this alternative eliminates all biological impacts on the Sampit River and Winyah Bay systems. An increase in chronic petroleum impacts and spill potential would be felt in the Savannah area.

2. **A smaller refinery at Georgetown**

This alternative would somewhat reduce the adverse effects of chronic discharges on the biota of the Sampit River and upper Winyah Bay, proportionately with the reduction in effluent volume. Also, since less oil would be transported, there would be a reduction in spill potential and therefore a concomitant reduction in threat to aquatic biota.

e. <u>Permit Action</u>

1. **Permit issuance**

The impacts from this alternative are the subject of this document. Environmental consequences on fish and wildlife resources from this alternative can be found in previous sections.

2. **Permit issuance with conditions**

This alternative could somewhat reduce adverse impacts to fish and wildlife resources by imposing requirements for further treatment of chronic pollutant components of the wastewater discharge and "best management" of stormwater runoff from the site. Also, conditions regarding "state of the art" safest shipping and handling procedures, as well as requirements for spill clean-up plans and equipment, could serve to reduce spill occurrence and impact.

3. **Permit denial**

This represents a "No Action" alternative and would eliminate refinery construction and operation impacts identified earlier in this document to the biota of the Sampit River and Winyah Bay systems.

5. **PARTICULAR SENSITIVITY OF THE WINYAH BAY SHORELINE TO OILING**

Substantial information relating physical habitats to oiling sensitivities is available in the literature (Gundlach et al., 1978; Hayes et al., 1980; Gundlach, 1980; Gundlach et al., 1981; Gundlach and Hayes, 1978; O'Sullivan, 1978; Hershner and Lake, 1980). The concensus of the literature is that sheltered tidal flats and marshes are the most sensitive environments to the effects of a spill. A sensitivity ranking index for coastal environments has been suggested by Gundlach and Hayes (1978), which ranks shoreline types on a scale of 1 to 10 based on predicted spill persistence and damage. The system is predicated on follow-up observations and studies of such classical tanker disasters as the <u>Amoco Cadiz</u>, <u>Metula</u>, <u>Argo Merchant</u>, <u>Florida</u> and <u>Torrey Canyon</u>. Sheltered tidal flats and salt marshes rank the highest (most sensitive), as numbers 9 and 10 respectively.

A table of shoreline environments has been prepared for Winyah Bay by the Research Planning Institute (Table VII.C-8). This table indicates that 80% of the shoreline environments of Winyah Bay fall into the most sensitive oil spill categories.

In addition to the particular sensitivity of the major portion of the Winyah Bay shoreline to oiling, the problems created by shallow water which preclude the deployment of containment booms and the density and weathering characteristics of heavy crude oil which reduce significantly or prevent the effectiveness of containment booms significantly increase the probability that even less-than-total-loss spills within Winyah Bay would be devastating to the bay's extensive fish and wildlife resources.

Table VII.C-8. Shoreline environments of Winyah Bay ranked in order of increasing spilled-oil persistence and biological damage (from DHEC-CEIP financed mapping study of the sensitivity of South Carolina shorelines to oil spills; T. W. Kana, RPI, principal investigator).

SHORELINE RANKING AND DESCRIPTION	MILES	PERCENT OF TOTAL
3. Fine-grained sand beaches	1.2	1
5. Mixed sand and shell beaches	11.6	9
5A. Exposed tidal flats of low biomass	4.1	3
6. Gravel or shell beaches	0.8	<1
7. Exposed tidal flats of moderate biomass	6.3	5
8. Man-made structures	2.2	2
9. Sheltered tidal flats	25.3	19
10. Marshes	80.6	61

Most oil-sensitive sheltered tidal flats and marshes comprise 80% of the Winyah Bay system (courtesy of Research Planning Institute, Inc.).

6. SUMMARY OF RESOURCES OF WINYAH BAY AND PROJECTED REFINERY IMPACTS

a. Summary of Resources

- o Winyah Bay is one of largest estuaries in the southeast, almost completely bordered by marsh.
- o Over 60,000 acres adjacent to the bay are set aside in perpetuity for the purpose of research, education and conservation.
- o 18 species designated as regional Species of Special Emphasis by the U.S. Fish and Wildlife Service utilize the Winyah Bay area.
- o Winyah Bay is the prime nesting area in South Carolina for the bald eagle.
- o Barrier beaches at the bay entrance are the second most utilized nesting area for loggerhead turtles in the State.
- o The Winyah Bay area represents the densest alligator population in the northern part of the State.
- o At least 30% of the waterfowl coming down the Atlantic Flyway utilize Winyah Bay for overwintering habitat.
- o Pumpkinseed Island in lower Winyah Bay is one of the largest wading bird rookeries in the U.S. (40,000 nesting birds).
- o Winyah Bay is the densest osprey nesting area in the State (over 150).
- o Documented loafing areas exist for brown pelican and other shorebirds.
- o Winyah Bay represents the principal anadromous fishery in the State for shad and sturgeon, as well as an important fishery for striped bass and herring.
- o Winyah Bay is the most important refuge for endangered shortnose sturgeon in its southern distributional area.
- o Winyah Bay provides excellent nursery habitat for estuarine species of commercial and recreational importance.
- o The shrimp catch in the vicinity of Winyah Bay and the Santee Delta represents 10% of the catch for the whole State.

b. **Summary of Impacts**

Impacts on Winyah Bay resources resulting from permitting the CRDC refinery can be divided into two categories: those that could result from refinery operation, and those that could result from an oil spill.

1. Impacts that could result from refinery effluent:

   - Destruction of aquatic life in the immediate vicinity of the outfall.
   - Reduction in value of the brackish aquatic nursery role of the Sampit River, particulary for more sensitive marine species.
   - Reduction in primary and secondary productivity in the Sampit River and Winyah Bay resulting in reduced viability of the systems to support commercial and recreational fishing.
   - Reduction in wildlife value of impoundments at Friend Field Plantation.
   - Degradation of shorebird, wading bird and waterfowl feeding areas in the Sampit River.
   - Lethal and sublethal effects on diving ducks that ingest contaminated sediments in the Sampit River.

2. Impacts that could result from an oil spill:

   - Destruction and long-term reduction in productivity, habitat values and other functions of emergent marshes in the Winyah Bay system.
   - Reduced viability of the Winyah Bay system to support commercial and recreational fishing through short-term destruction and long-term changes in the abundance and composition of supporting biotic elements including phytoplankton, zooplankton and benthic communities which would result in reduction of primary and secondary productivity throughout the Winyah Bay system.
   - Reduction and possible loss of aquatic nursery functions in Winyah Bay through oiling of marshes, flats and shallows.
   - Direct lethal and sublethal impacts on fishes and shellfish, particularly bottom-dwelling species such as flounder, the endangered shortnose sturgeon, shrimp and crabs.

- Direct lethal and sublethal impacts on wading birds, shorebirds, waterfowl and raptors that come in contact with spilled oil.

- Loss of wading bird feeding and nesting habitat including the loss of Pumpkinseed Island as a rookery.

- Contamination of private and State-owned waterfowl impoundments.

- Introduction of oil into the pristine North Inlet system, resulting in reductions of primary and secondary productivity, loss of nursery habitat and fisheries utilization, loss of wading bird feeding habitat and disruption of nationally significant research.

- Contamination of the lower Santee River and Cape Romain systems.

- Fouling of beaches adjacent to Winyah Bay and extending in worst case circumstances as far north as Garden City Beach and as far south as Cape Romain National Wildlife Refuge.

VII.

E. Socio-Economics

1. Land-Use Changes

Since land use plans have already been formulated and accepted by the local community, no significant changes in land use are expected from the construction and operation of the oil refinery on a site zoned for industrial development. This is discussed in detail on page VII.C-48 to 50.

2. Community Structure

Since most of the employees for the oil refinery will be hired locally, no significant impacts on community structure are anticipated.

3. Public Services

Electricity for the refinery will be generated on-site using fuel gas produced at the refinery to fuel a gas turbine. Exhaust gas from the turbine will be used within the refinery to heat various process streams, thereby recovering a significant amount of energy from the turbine exhaust. Process water for the refinery will be provided by deep wells on-site. There will be a significant amount of water reuse within the refinery. There should be no significant impact on the housing, medical and school demands in Georgetown County since the majority of the employees will be hired locally. A private security system utilizing guards or night watchmen will be provided on site; however, their jurisdiction will not extend beyond the property boundaries of the project site. Their primary function will be monitoring the passage of people and products in and out of the refinery. No additional local police protection is expected to be necessary as a result of this project.

On-site fire-fighting equipment will include portable fire extinguishers, fire hydrants and hoses which will be located strategically around the plant site in all areas where a fire could occur. Smoke and/or flame detectors and alarms will be installed in unmanned areas such as the warehouse and other areas where these devices will be effective. Signs or other warning devices will be posted in all critical areas such as where smoking or open flames are not permitted and all rules and regulations regarding fire prevention will be strictly enforced. A fire protection contract with the City of Georgetown will be obtained. Existing equipment and fire fighting capabilities of this unit should be adequate to serve the refinery, therefore, additional fire protection services will not be required as a result of this project.

4. Tourism. As noted in Section VI, the major part of the tourist industry in Georgetown County is concentrated north of Georgetown along the coast at Huntington Beach, Murrells Inlet, Litchfield Beach and Pawleys Island. The oil refinery is not expected to have significant adverse impacts on these areas.

5. Transportation. The operation of the refinery would increase ship traffic by five to six ships per month. These tankers would enter Georgetown Harbor loaded with oil and would leave the port loaded with ballast water. Although it is expected that most of the finished products would be distributed within the service area by tanker truck, some would probably be transported by barge. Truck traffic would be increased by an estimated 100 to 150 tanker trucks per day. This is a significant increase in traffic on S.C. Highway 42 (Pennyroyal Road) which would increase maintenance costs by an undetermined amount.

6. Employment and Income.

a. Refinery-related. The proposed refinery would employee approximately 100 people, most of whom would be technicians and laborers. Approximately 90 percent of these people would be hired locally and trained. The economic impact from a plant opening includes more than its associated employment and earnings gains. The initial gain in employment and earnings generates a ripple or multiplier effect resulting in additional employment and earnings in other industries. These additional employment and earnings are generated by the increase in purchases of the workers employed by the new plant, and earnings that are generated in the provision of the purchased goods and services. The magnitude of these effects depends on the expenditure pattern of the workers (how much and where they will spend their earnings on goods and services) and how and where those goods and services will be produced. An analysis of the impact of companies likely to locate in Georgetown was generated by a model used by Floyd and Little[6]. The individual impact of eight different types of industries that were identified as possible candidates to locate in Georgetown was analyzed. For a petroleum refinery with 90 direct employees, about 40 additional employees would be expected to be hired in other industries due to the indirect and induced effect resulting from local spending multipliers. The average direct wage in a petroleum refinery is about $28,000 annually. The total related payroll for the petroleum refinery, including direct and indirect employment, would be about 2.9 million dollars annually. Employee related local taxes would be expected to be about $47,000 annually.

b. Income from Fish and Wildlife. According to the National Marine Fisheries Service, the landings of approximately 400 fishermen from 200 boats fishing in Winyah Bay and vicinity ranged from $518,126 to $2,206,092 with an average of $1,398,373 during the 1978-82 period. A dollar value has not been established for recreational fishing, but as noted on page VI.D-29, recreational fishing pressure in Winyah Bay is low in comparison to other major estuaries in South Carolina. According to the S.C. Wildlife and Marine Resources Department, the total annualized cost for waterfowl impoundments in the Winyah Bay area is approximately $1,300,000 and annual management costs are over $600,000.

In accordance with the evaluation in Table V.I, normal refinery operation should not have an unacceptable effect on the fish and wildlife resources of Winyah Bay. There are so many variables that would collectively determine the damage caused by a spill such as the size and location of spill, substance spilled, effectiveness of control and clean-up efforts, etc. that it appears impractical to attempt to quantify losses to these resources. However, in a "worst case" spill of 42,000 barrels that is accompanied by conditions and situations that maximize the spread of oil and minimize the effectiveness of control and clean-up efforts, the aquatic resources of Winyah Bay and the economic base they support could be severely damaged for a long period of time.

7. Potential Port Development

a. Industrial Location Factors. The Georgetown Port and Industrial Development Study[7] addressed potential industrial development opportunities for Georgetown County. The potential industrial opportunities were

[6] Davis and Floyd, Inc. and Arthur D. Little, Inc., June 1983. Georgetown Port and Industrial Development Study.

[7] Ibid.

developed by evaluating and matching industries' locational and business characteristics with the features of the county, and by conducting interviews with potential industries. The industrial categories included forest products, high technology, chemical, machinery manufacture, ship repair, petroleum refining, food and agribusiness, construction materials, iron and steel. The results of this study are summarized in Table VII.D-8.

b. Economic Constraints. The principal restraint on the greater use of Georgetown Harbor by local industries is the lack of regular service by ocean freight lines. However, attempts to obtain regular shipping service have failed because of insufficient cargo. Davis and Floyd and Arthur D. Little[8] conclude that 15,000 tons of cargo per month would be required to attract regular service by freight lines.

8. Secondary Development. The proposed refinery site and its vicinity are zoned for industrial development and could be so developed regardless of the outcome of this permit application. The applicant does not have any plans for additional development nor does it have any specific requirements for additional development by others. There are no known plans by any other

[8] Davis and Floyd, Inc. and Arthur D. Little, Inc., June 1983. Georgetown Port and Industrial Development Study.

TABLE VII-D-8
MAJOR ADV/ ;ES AND DISADVANTAGES AFFECTING LIKELIHOOD OF LOCATION BY VARIOUS INDUSTRIES IN GEORGETOWN[1/]

Industry Category	Material Supply	Market Location	Existing Capacity	Labor Supply	Labor Unions	Coastal Quality of Life	Interstate Highway	Environmental Factors	Site Availability	Harbor/Port Facilities	Financi Assista
Forest Products											
-Primary (e.g., pulp)	+			+	-				+		
-Converted	+	-	-								
High Technology Industries											
-Manufacturing and Assembly				+	-	+			*		*
-Research and Development				-	-	+			*		*
-Sales and Distribution		-			-		-		*		*
Chemical Industries											
-Primary and Downstream Petrochemicals (ethylene and derivatives)			-								
-Naval Stores (gum and wood)	+			+							
-Textile and Forest Product Supplies		+		+							
-Explosives				+							
-Plastic Products		+		+							
-Other Specialty (e.g., pharmaceuticals)				-			-		+		
Machinery Manufacture											
-Export					-				+	+	
-Textile		+		+							
-Other Domestic/Heavy		-	-								
Ship Repair		+	+						-	+	
Petroleum Refining			- 2/					-	+	+	
Food and Agribusiness											
-Supplies		-			-						
-Fish Production/Processing	-		-	+	-					+	
-Poultry Production/Processing	+	+			-						
-Other Primary/Intermediate Products	-				-						
-Final Products		+		+	-						
Construction Materials		-	-								
Iron and Steel (Downstream Products)	+	-	-								

Key: + Indicates important potential advantage for Georgetown.
- Indicates important potential disadvantage for Georgetown.
Blanks insidcate expectation that other factors would control decision.
* Site and financial assistance of the form traditionally provided by ir` strial revenue bonds would be a necessity to compete with other lo-ations.

1/ Davis Floyd, Inc., Arthur D. Little, Inc., Summary of Phase II Report, Georgetown Port and Industrial Development Study, South Carolina Po.ts Authority, Jun

2/ The minus sign reflects the worldwide decline in the demand for petroleum products. However, in conclusion, the refinery is viewed as a unique opportunity for Georgetown by the Phase II Report.

industry for development in this area. However, industries having a large fuel requirement such as coke facilities, chemical plants, and plastic and synthetic fiber plants might find it advantageous to be located near a refinery. In the absence of any specific proposals for secondary development an evaluation of environmental impact must be quite general.

a. Impacts on Air and Water Quality. Any potential secondary industrial development would be subject to state and Federal review concerning air emissions and liquid effluents and would not receive the necessary permits if its proposed emissions or effluents would exceed state or Federal standards and criteria. Any increase in air or liquid effluents could degrade air and water quality. However, the significance of the potential degradation of air and water quality by any possible secondary development can not be determined without specific proposals for development.

b. Land-Use Changes. Any potential secondary industrial development on adjacent property would result in changes similiar to those ascribed to the development of the refinery site itself. This would include the clearing of cut-over pine-hardwood areas and the loss of habitat for birds and mostly small mammals. This would not result in the loss of any habitat that is not abundant in coastal South Carolina. Public use would not be affected because this area is not available for public use.

c. Demands on Public Service. Any secondary industrial development would increase traffic on local roads and the demands on public services in direct proportion to the numbers of people employed and also in proportion to the volume of raw materials, supplies, and products that must be transported. Georgetown would experience costs in providing these services, but would also gain economic benefits from taxes and the employment of additional workers.

E. Aesthetics

The construction of a refinery on Harmony Plantation would alter the appearance of the site from that of a cut over pine-hardwood area to that of an industrialized area. This alteration would reduce the aesthetic qualities of this area. However, the relative isolation of the refinery site should greatly reduce the extent that it would infringe on the view of those occupying neighboring properties. This area has been zoned for industrial development, so the location of a refinery here is compatable with zoning regulations.

. Noise

Principal noise sources during the daytime only construction phase of the proposed refinery include earth-moving equipment, material handing equipment, stationary equipment, and impact equipment. The noise level from this equipment may reach as high as 90-100 decibels in the immediate vicinity of the particular activity. However, this will attenuate to approximately 50-55 decibels at the refinery property limits. During operation, the principal sources of noise would be cooling towers, cooling pumps, etc. (as listed below).

cooling towers
cooling pumps
air conditioning and ventilation pumps
air compressors
boilers and steam generators
electrical distribution system
pumps throughout the refinery
employee traffic, maintenance traffic and transportation of raw materials and products

F. Cultural Resources

The property on which the proposed refinery is to be located is part of a much larger tract owned by the South Carolina State Ports Authority. The area immediately south of the refinery tract is to be utilized as a dredged material disposal area by the U.S. Army Corps of Engineers. As part of the planning and design for the disposal area, the Corps of Engineers contracted with Carolina Archeological Services of Columbia, South Carolina, to perform an intensive overview investigation of the cultural resources potential in that area. (Findings reported in "A Cultural Resources Overview of Harmony Plantation, Georgetown Harbor, South Carolina", Carolina Archeological Services, April 1981, Dr. L. Drucker, Principal Investigator.) This archeological survey produced only two single isolated finds of artifacts and no archeological or structural sites were identified; nor were any indicated by documents, archival sources or local informants who are quite familiar with the property and its 20th Century land use. The report of this survey concludes that the high, sandy pine barrens of the general area have an extremely low potential for containing archeological sites, but that the shoreline of Pennyroyal Creek and Sampit River north of disposal site (i.e., in the vicinity of the refinery tract) does contain at least three archeological sites and has a high potential of containing more. Recommendations were made in the report regarding the potential extent of the archeologically sensitive area and reconnaissance required to assess the presence of sites.

In response to these recommendations, the applicant relocated the proposed refinery facilities so that no work will occur within the identified archeologically sensitive area, thus precluding any potential for impacts on Sites H-1, H-2, and H-3, or other presently unknown cultural resources.

The alignment of the proposed pipeline is well removed from the location of Sites H-1, H-2, and H-3 and traverses areas outside of the identified "potentially archeologically sensitive" zone, as extended down the shoreline. The character of the area to be traversed is similar to that described above which has "an extremely low potential for containing archeological sites". Consequently, further investigations are not warranted.

The proposed refinery site is located at least three miles from the City of Georgetown Historic District. The proposed work will in no way effect the characteristics which qualified this area for inclusion in the National Register of Historic Places.

G. Hurricane Effects

1. Hurricane Probability. Although hurricanes have often been called "September gales," they have occurred along the South Carolina coast as early as 28 May and as late as 23 October. This represents a fairly narrow time frame, since tropical cyclones have hit the Gulf or Atlantic coasts as early as 2 February or as late as 2 December. The Sea Island Coastal Region is a moderately high risk zone with respect to tropical cyclone occurrences and destruction. Purvis and Landers (1973) report that 169 hurricanes hit the South Carolina coast from 1686 to 1972 for an average of 0.59 per year.

2. Hurricane Effects. Storm tides or surges add substantially to the destruction caused by hurricane-force winds. Myers (1975) has defined a storm tide as the height of the sea surface above local MSL during a storm, and a surge as the increase (or decrease) of the height of the sea surface due to a storm. Much information relating to storm tides along the South Carolina and Georgia coasts can be found in Ho (1974) and Myers (1975). One of the best documented storm tides in the Sea Island Coastal Region was that of the August 1940 hurricane, which struck the Georgia-South Carolina coast just north of Savannah. High-water marks were measured in 1971, utilizing the National

Geodetic Vertical Datum of 1929 (Myers 1975). Flooding from Savannah to Charleston occurred with storm tides of 2.3 m (7.4 feet) at Savannah, 4.4 m (14.5 feet at Beaufort, and 2.7 m (8.9 feet) at Charleston being recorded (Ho 1974, Myers 1975). Even higher storm tides have been recorded, thus illustrating the potential for severe destruction along the South Carolina-Georgia coast. According to the S.C. State Climatologist, a category 5 hurricane (150 mph winds) could cause a storm time 20 feet above mean sea level (msl) at Georgetown, but a more likely elevation would be 10 to 12 feet msl. The refinery should not be significantly affected by such a tide since the site is above the 20-foot contour.

The proposed refinery will be designed to withstand the full force of a hurricane and associated high water. This is necessary to protect the capital investment of the refinery if a hurricane should occur. Also, since the possibility of a hurricane does exist, the refinery will be designed to withstand such an occurrence as a matter of safety and good engineering practice.

H. Impact of Oil Spills on Ground Water

Oil spilled onto the ground will tend to flow downward, with some lateral spreading. The rate of oil movement in the soil will depend on oil viscosity, soil properties, and the rate at which the oil has been spilled. As oil moves downward through soils, some of it becomes trapped between individual soil particles and remains behind the main body of oil, which may eventually reach the water table. Thus, the volume of the original oil is continually depleted as it migrates through the soil. In some spills, the volume of the oil is insufficient to reach the water table and remains trapped in the soil. As rainwater later percolates through this zone, some droplets of oil that are weakly attached to the soil will break loose and flush away (American Petroleum Institute, 1980, p. 4, 6).

As the body of spilled oil moves downward, its course is affected by variations in permeability of the soil layers through which it passes. Should the oil encounter an impermeable layer, it will spread laterally, until it becomes immobile or until it comes to the surface where the layer outcrops. Downward movement may be additionally complicated by the presence of thin lenses of clay or other low-permeability material (American Petroleum Institute, 1980, p. 6).

Oil infiltration first occurs by gravity, and if the amount of oil is greater than the retention capacity of the sediments it will reach the capillary fringe of the ground water. A minimal thickness of oil must be established above the capillary zone before lateral migration can occur (Van Dam, 1967). As descending oil approaches the water table, it cannot displace much of the capillary water. Therefore, it will move downward around the water-filled pores and through the larger pores until it encounters water which it cannot bypass. The weight of the oil will depress the water table and the capillary zone will follow it downward, since each capillary must remain attached to its source. The amount of oil at any position in the capillary zone will depend on the amount of capillary water present. The least oil will be near the bottom of the zone, which is heavily saturated with water, and the most oil will be at the top, where there is less water saturation (American Petroleum Institute, 1980, p. 11).

The amount of water in the capillary zone inhibits the lateral movement of the oil. In the upper portion of the zone, where there is little water, the oil may move with only minor interference. Near the middle, movement will be greatly restricted. And, in the lower portion, movement may not be possible at all (American Petroleum Institute, 1980, p. 11).

Consequently, a body of spilled oil will spread over and through the capillary zone. Eventually, with enough time and no addition of new oil, the layer of oil will reduce to a critical thickness and stop moving. The thickness is determined by existing permeability and gradient. The ultimate thickness of the mobile oil will be only a fraction of the thickness of the capillary zone.

A sudden, large-volume spill will depress the water table and spread in all directions in a layer above the water table. As the layer becomes thinner, it will begin to move in the direction of ground-water flow. A slower leak will descend in a narrow cone and spread in the direction of water movement. Lateral spreading will usually be slower than the flow rate of the ground water (American Petroleum Institute, 1980, p. 7). The shallow aquifer in the study area consists of approximately 25 feet of sand underlain by at least an additional 20 feet of sand with shell (Glowacz, 1980b, p. 56) and is recharged locally; therefore, the shallow ground-water system will probably behave similarly to the preceding discussion.

Fried and others (1979, p. 593) conclude by their experiments that the movement downstream of the oil is governed by dispersion-convection which carries, spreads, and diffuses the hydrocarbon traces. These authors stressed that a body of hydrocarbons which has reached the water table several meters below land surface will have a life time measured in tens of years. The water-table aquifer area as described by Glowacz (1980a) may react similarly. Much of the delay is due to chemical and physical phenomena which modify the purely dispersive movement of the pollution, through absorption, biochemical decay, and evaporation (Fried and others, 1979, p. 592).

In order to evaluate the impacts that might result from an oil spill, more information would be necessary on the hydrology and hydraulic factors of the area and the use that is being made of the aquifer. The more important factors are the direction of ground-water flow in the shallow aquifer to the point of discharge, hydraulic gradient, porosity of sediments near the water table, hydraulic conductivity of the sediments, and the percolation rate from the land surface to the water table.

Many of the factors that can make an oil spill on water very difficult to control and clean up are not applicable to land spills. Such spills are not susceptible to spread by tides and wind and various kinds of equipment can be readily brought into operation to control the spread of oil and clean up all spilled oil in a relatively short time. Because of the relative ease with which spilled oil can be retrieved plus the great improbability of a large spill ever occurring, the Corps believes there is little potential for pollution of aquifers by an oil spill.

I. Impact of Ground Water Withdrawals

The present concept is for the refinery to obtain about 973,000 gallons of process water per day from wells on the refinery site. The number and depth of wells has not yet been determined. Possible sources include shallow tertiary aquifers, the Pee Dee formation, and the Black Creek Aquifer.

The shallow tertiary aquifer and the Pee Dee formation could provide only a portion of the refinery's need for ground water. Excessive withdrawals from these aquifers could deplete the resource and adversely affect other users. Saltwater intrusion could result from excessive withdrawals.

The Black Creek aquifer is a much more likely source of water for the refinery. Shallow parts of this aquifer are now being used by the City of Georgetown, Maryville and Georgetown County. The deeper parts are not now being used, but some abandoned wells formerly yielded large amounts of water. The Black Creek Aquifer therefore appears to be the best source of ground water for the refinery and the one least likely to have a significant impact on the resource.

The permitting system administered by the S.C. Water Resources Commission (See page VI.J-3) is designed to prevent depletion of ground water resources or their degradation by saltwater intrusion and should insure that ground water resources are protected.

LIST OF PREPARERS

The following people were primarily responsible for preparing the Environmental Impact Statement:

Name	Discipline/Expertise	Experience	Role in Preparing EIS
John Carothers	Biology/Fish & Wildlife	3 years, Biologist, Ala. Conservation Dept.; 3 years, Biologist, U.S. Fish & Wildlife Service; 17 years, Biologist, Corps of Engineers	EIS Coordinator, evaluation of Alternatives, Summary, and Public Involvement
Jim Woody	Biologist/Environmentalist	8 years, Environmentalist, Corps of Engineers	Sections on Alternatives, Climate, Cultural Resources, and Research Institutions.
Moss Mills	Economist/Water Resource Development	17 years, Regional Economist, Corps of Engineers	Socio-Economics Section
James N. Cahill	Groundwater/Hydrology	31 years Hydrologist, U.S.G.S	Geology, Stratigraphy and Groundwater Evaluation Sections

LIST OF PREPARERS

Name	Discipline/Expertise	Experience	Role in preparing EIS
Mr. R.B. Howard	Engineering/Civil and sanitary engineering	10 yrs, EIS preparation, USEPA	Project officer for air and water quality, U.S. Environmental Protection Agency
Mr. W. Bowman Crum	Environmental/Water quality Science	5 yrs, EIS preparation, USEPA and USDHUD; 5 yrs, environmental consultant, Davis and Floyd, Inc. and Enwright Associates, Inc.; 2 yrs, biologist, SC Pollution Control Authority; 3 yrs, biologist, Academy of Natural Sciences of Philadelphia	Project Monitor for air and water quality, U.S. Environmental Protection Agency
Dr. N. Walls	Microbiology,/Environmental Botany, management, Chemistry biochemistry	1 yr, microbiology instructor, Emory University; 10 yrs, research biologist, Georgia Institute of Technology Engineering Experiment Station; 15 yrs, associate professor of biology, Georgia Institute of Technology; 10-1/2 yrs, President, Applied Biology, Inc.	Project Manager for air and water quality, Applied Biology, Inc.
Dr. T. Rachford	Civil Engineering/Environmental planning, water resources	1 yr, assistant engineer, Kentucky DNR; 4 yrs, assistant professor of civil engineering, Pennsylvania State University; 11 yrs, consulting in environmental planning and water resources, Gannett Fleming Corddry and Carpenter, Inc.	Project Manager for air and water quality, Gannett Fleming Corddry and Carpenter, Inc.
Dr. E. Zillioux	Marine Science/Aquatic ecology, fate and effects of toxic substances	3 yrs, aquaculture and plankton physiology, U.S. Naval Research Lab.; 3 yrs, zooplankton environmental requirements, National Marine Water Quality Lab.; 6 yrs, trophodynamics of plankton populations, plankton toxicology, Univ. of Miami; 4 1/2 yrs, ecological consulting, Connell Metcalf and Eddy; 2 yrs, environmental effects of toxic substances, USEPA; 3 yrs, consulting in ecology and toxicology, Environmental Assessments, Inc. and Applied Biology, Inc.	Project Director for air and water quality; process waters characterization, regulation and fate
Mr. W. Jacobs	Chemistry/Air pollution monitoring and assessment	19 yrs, air quality control, Allied Chemical Corp.; 14 yrs, consulting in air quality monitoring and assessment, Gannett Fleming Corddry and Carpenter, Inc.	Air quality management
Mr. D. Babcock	Environmental/Water resources Engineering	7 yrs, consulting in water resources engineering and management, Gannett Fleming Corddry and Carpenter, Inc.	Effects of construction, sanitary wastewaters and plant runoff; applicable regulations
Ms. N. Bechler	Geography/Editorial review, report coordination	7 yrs, editorial review and project coordination, Soil Systems Inc. and Applied Biology, Inc.	Document production coordinator for air and water quality sections

Revised 4-12-84

LIST OF PREPARERS
(continued)

Name	Discipline/Expertise	Experience	Role in preparing EIS
Mr. K. Jacobs	Chemistry/Air quality assessment	1 yr, analysis of wastewater samples, O'Brien and Gere Engineers, Inc.; 4 yrs, air quality monitoring and assessment, Gannett Fleming Corddry and Carpenter, Inc.	Air quality alternatives; affected environment; impacts of refinery operation
Dr. T. King	Environmental/Water resources, Engineering agricultural and civil engineering	1 yr, drainage system design, Connell Associates, Inc.; 3 yrs, consulting in environmental engineering and river basin modeling, Connell Metcalf and Eddy, Inc.; 6 yrs, teaching and research on agricultural waste and wastewater treatment, Clemson University	Impacts of oil spills; analysis of spill probability models
Dr. J. May	Geology/Coastal geology, computer modeling	2 yrs, petroleum geologist, Texaco Inc.; 3 1/2, yrs-geologist and groundwater specialist, Florida DNR; 1 yr, professor of geology, Arizona State University; 8 yrs, professor of geology, the Citadel	Spill trajectory modeling
Mr. S. Sides	Chemistry /Air pollution Environmental control, industrial Health hygiene	1 yr, evaluation of chemical pollution data related to energy resource development, USEPA; 1 yr, consulting in industrial hygiene, Sentry Insurance Company; 5 yrs, air pollution control and toxic substance management, Gannett Fleming Corddry and Carpenter, Inc.	Air quality impacts
Mr. K. Stockwell	Environmental/Water resources, Engineering hydrology	2 yrs, water resources research, Old Dominion Univ.; 1 yr, consulting in water quality and environmental management, Applied Biology, Inc.	Water quality alternatives; affected environment; cumulative effects
Mr. F. Swit	Water Resources/Water resources Engineering management, geology and soils	4 yrs, public health technician, U.S. Air Force; 10 yrs, consulting in water resources, Gannett Fleming Corddry and Carpenter, Inc.	Sediments of affected environment; impacts on sediments and sediment transport
Mr. D. Webster	Marine Science,/Marine ecology, Biology chemistry	8 yrs, plankton studies, quality control and marketing director, Applied Biology, Inc.	Impacts of oil spills; mitigative measures

LIST OF PREPARERS

The following people were primarily responsible for preparing this fish and wildlife resource and impact section of the Environmental Impact Statement for the CRDC Refinery at Georgetown, S.C.

Name	Discipline/ Expertise	Experience	Role in Preparing EIS
Roger Banks	Biology/Wildlife	3 yrs. Fish & Wildlife Biologist/ USFWS, 7 yrs. Supervisor/USFWS	Conditions and Impacts at Plant Site (Section VII.C-1)
Prescott Brownell	Zoology/Wildlife Biology/Fishery Biology	2 yrs. Marine Biologist/ S.C. Wildlife & Marine Res. 5 yrs. Fish & Wildlife Biologist/ USFWS	Wildlife Resources, Terrestrial System (Sections VI.D-1, VI.D-2)
Diane Duncan	Zoology/Marine Science	3 yrs. Aquatic Biologist/ Coastal Zone Resources Corp. 5 yrs. Fish & Wildlife Biologist/ USFWS	Impacts of Chronic Discharges and Oil Spills (Section VI.C-2)
Karen Harper	Biology/Botany	4 yrs. Biologist/USFWS	Wetlands (Section VI.D-3)
Steve Gilbert	Biology/Estuarine Ecology	2 yrs. Biologist/Fla. Game & F.W. Fish Commission, 6 yrs. Fish & Wildlife Biologist/ USFWS	EIS Coordinator for Fish and Wildlife Sections, Preparation of all other sections. (Sections VI.D-4 through 9, VII.C-1 through 9)
Lois Mishoe	Word Processer	6 yrs. Secretary/USFWS	Manuscript preparation

IX. PUBLIC INVOLVEMENT

A public notice was issued on 3 December 1979 announcing the receipt of a permit application from Carolina Refining and Distributing Company on 20 November for work in the Sampit River at Georgetown. This public notice described the proposed work, stated that a preliminary review indicated that an EIS was not required, and invited comments from all concerned. Many comments were received from natural resource agencies and organizations requesting that an EIS be prepared. The major concern was the potential for oil spills and the resultant damage to the natural resources of Winyah Bay.

Because a number of questions pertaining to potential oil spills had not been addressed in the preliminary environmental assessment, the Charleston District prepared and distributed a revised environmental assessment on 4 May 1981 to everyone who had commented on the public notice. Recipients were asked to review the additional information in the revised environmental assessment and to comment on the proposed project. Approximately twenty letters were received.

A joint public hearing with the S.C. Water Resources Commission was held on 8 October 1981 to provide an opportunity for additional public comment for consideration by the Charleston District and the Water Resources Commission before reaching a final decision on the permit application.

After it was decided to prepare an EIS, a Notice of Intent to Prepare an EIS was published in the Federal Register on 18 July 1983. This Notice of Intent described the proposed action and possible alternatives and significant issues to be addressed in the EIS. It also stated the intent of the Charleston District to ask the U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and the U.S. Coast Guard to serve as cooperating agencies in the preparation of the EIS. The time and location of a scoping meeting were included and the public was invited to participate in the scoping process by submitting suggestions to the Charleston District.

A scoping meeting was held at the Federal Building in Charleston, S.C. on July 22, 1983 with approximately 50 persons in attendance. An EIS and permit schedule was provided to participants, prompting some discussion of whether or not an adequate EIS could be completed without additional detailed studies of Winyah Bay. Participants were told that the Corps' evaluation of the existing data base indicated it was sufficient and that additional detailed studies were unnecessary. A table showing six broad categories of environmental impacts that could result from either the normal operation of the refinery or from oil spills was then passed out for the review and comment of attendees. Representatives of the National Marine Fisheries Service, Fish and Wildlife Service, Environmental Protection Agency, and the Coast Guard were introduced and it was announced that these agencies were being requested to participate as cooperating agencies in the preparation of the EIS. Representatives of the Charleston District and the four cooperating agencies took up separate positions in the meeting room to receive suggestions from attendees on specific impacts which should be addressed in the EIS. The suggestions received during this informal session were recorded on large sheets of paper which were then displayed before the entire group for informal discussion. An array of alternatives was then presented for discussion. Suggestions for any additional alternatives were solicited from the audience, but none were offered. All alternatives presented at the scoping meeting are addressed in this EIS. Afterwards, the District forwarded copies of all letters containing suggestions for the EIS to the cooperating agencies receiving EIS assignments.

The Charleston District held a public meeting in Georgetown on December 8 1983 to inform the public of the procedures adopted for preparing the EIS and of the progress achieved, and to provide an opportunity for interested persons to question those who would prepare the EIS. Another public meeting was held on April 26, 1984 to receive comments on the draft EIS which had been released on April 4. Approximately 150 persons attended this last hearing. A show of hands of those present indicated a ratio of three to one in opposition to issuance of a permit.

The draft EIS was distributed to the following:

Honorable Strom Thurmond, U. S. Senator
Honorable Ernest F. Hollings, U. S. Senator
Honorable Robert M. Tallon, U. S. Representative
Honorable F. F. McConnell, S. C. State Senator
Honorable W. P. Cantrell, S. C. State Senator
Honorable T. D. Wise, S. C. State Senator
Honorable A. Ravenel, Jr., S. C. State Senator
Honorable W. W. Doar, Jr., S. C. State Senator
Honorable J. J. Snow, Jr., S. C. State Representative
Honorable R. L. Altman, S. C. State Representative

U. S. Geological Survey
Advisory Council on Historic Preservation
Agriculture Stabilization & Conservation Service
U. S. Forest Service
Soil Conservation Service
U. S. Department of Energy
U. S. Environmental Protection Agency
Federal Emergency Management Administration
Federal Maritime Commission
U. S. Department of Health and Human Services
U. S. Department of Housing and Urban Development
U. S. Department of Interior
U. S. Coast Guard
Federal Highway Administration
U. S. Department of Commerce
S. C. State Clearinghouse
Waccamaw Regional Planning and Development Council
Georgetown County Council
Georgetown County Chamber of Commerce
Georgetown County Development Commission
Mayor of Georgetown
Georgetown Bar & Harbor Pilots Association
National Wildlife Federation
S. C. Wildlife Federation
National Audubon Society
Charleston Natural History Society
Georgetown County Historic Foundation
League of Women Voters
Sierra Club
Georgetown Propellor Club
Baruch Institute

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GERALD S. BALLARD SR.
MARK O. BARA
L. D. BARDEN
MS. SANDRA W. BARDEN
DONNA LYNN BARKER
DAVID M. BARTLES
RICK BAUMAN
HARRY S. BELL
MR. STEVE BENNETT
FREDDIE BESSELIEU
TERRY BIDLEMAN
GEORGE F. BOURNE

GILLESPIE G. BOYD
JOHN BRASINGTON
WILLIAM R. BREEZE
MR. BO BRICKLEMYER

BUBEN DAVIS
THOMAS P. DAVIS
DENNIS DAYE
KEITH E. DEAN
DION DELEONE
MS. MARY DEMETRIOUS
G. WILLIAM DESOUSA
MR. RICK DEVOE
WILLIAM W. DOAR JR.
DAVE DONMOYER
INGELL H. DOYLE
MR. BILL DREYFOOS
VIRGIL DUGAN
JERRY DYER
JOHN E. DYER
CYNTHIA EAYRE
JOHN C. EDWARDS
CHARLES C. ELLIOTT
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Sixty-six letters of comment were received on the draft EIS. No new substantative issues were identified by reviewers. Appendix B consists of all letters from agencies and those non-agency letters containing specific comments on the draft EIS and responses thereto. Appendix C consists of letters that do not contain specific comments on the draft EIS and which therefore do not require a specific response in the final EIS.

END

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